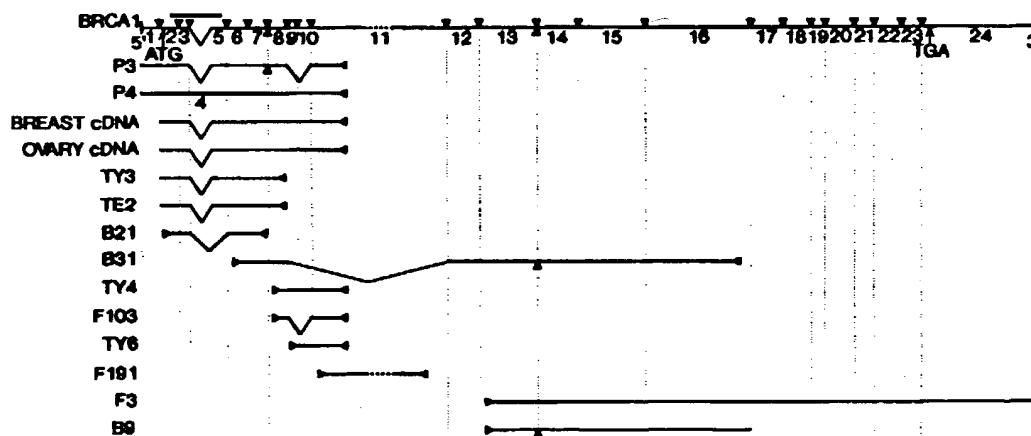


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(54) Title: IN VIVO MUTATIONS AND POLYMORPHISMS IN THE 17q-LINKED BREAST AND OVARIAN CANCER SUSCEPTIBILITY GENE**(57) Abstract**

The present invention relates generally to the field of human genetics. Specifically, the present invention relates to methods and materials used to isolate and detect a human breast and ovarian cancer predisposing gene (BRCA1), some mutant alleles of which cause susceptibility to cancer, in particular breast and ovarian cancer. More specifically, the invention relates to germline mutations in the BRCA1 gene and their use in the diagnosis of predisposition to breast and ovarian cancer. The present invention further relates to somatic mutations in the BRCA1 gene in human breast and ovarian cancer and their use in the diagnosis and prognosis of human breast and ovarian cancer. Additionally, the invention relates to somatic mutations in the BRCA1 gene in other human cancers and their use in the diagnosis and prognosis of human cancers. The invention also relates to the therapy of human cancers which have a mutation in the BRCA1 gene, including gene therapy, protein replacement therapy and protein mimetics. The invention further relates to the screening of drugs for cancer therapy. Finally, the invention relates to the screening of the BRCA1 gene for mutations, which are useful for diagnosing the predisposition to breast and ovarian cancer.

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TITLE OF THE INVENTION

IN VIVO MUTATIONS AND POLYMORPHISMS IN THE 17q-LINKED BREAST AND
OVARIAN CANCER SUSCEPTIBILITY GENE

5 FIELD OF THE INVENTION

The present invention relates generally to the field of human genetics. Specifically, the present invention relates to methods and materials used to isolate and detect a human breast and ovarian cancer predisposing gene (BRCA1), some mutant alleles of which cause susceptibility to
10 cancer, in particular, breast and ovarian cancer. More specifically, the invention relates to germline mutations in the BRCA1 gene and their use in the diagnosis of predisposition to breast and ovarian cancer. The present invention further relates to somatic mutations in the BRCA1 gene in human breast and ovarian cancer and their use in the diagnosis and prognosis of human breast and ovarian cancer. Additionally, the invention relates to somatic mutations in the BRCA1 gene in other
15 human cancers and their use in the diagnosis and prognosis of human cancers. The invention also relates to the therapy of human cancers which have a mutation in the BRCA1 gene, including gene therapy, protein replacement therapy and protein mimetics. The invention further relates to the screening of drugs for cancer therapy. Finally, the invention relates to the screening of the BRCA1 gene for mutations, which are useful for diagnosing the predisposition to breast and ovarian cancer.

20

The publications and other materials used herein to illuminate the background of the invention, and in particular, cases to provide additional details respecting the practice, are incorporated herein by reference, and for convenience, are referenced by author and date in the following text and respectively grouped in the appended List of References.

25

BACKGROUND OF THE INVENTION

The genetics of cancer is complicated, involving multiple dominant, positive regulators of the transformed state (oncogenes) as well as multiple recessive, negative regulators (tumor
30 suppressor genes). Over one hundred oncogenes have been characterized. Fewer than a dozen tumor suppressor genes have been identified, but the number is expected to increase beyond fifty (Knudson, 1993).

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The involvement of so many genes underscores the complexity of the growth control mechanisms that operate in cells to maintain the integrity of normal tissue. This complexity is manifest in another way. So far, no single gene has been shown to participate in the development of all, or even the majority of human cancers. The most common oncogenic mutations are in the H-ras gene, found in 10-15% of all solid tumors (Anderson *et al.*, 1992). The most frequently mutated tumor suppressor genes are the TP53 gene, homozygously deleted in roughly 50% of all tumors, and CDKN2, which was homozygously deleted in 46% of tumor cell lines examined (Kamb *et al.*, 1994). Without a target that is common to all transformed cells, the dream of a "magic bullet" that can destroy or revert cancer cells while leaving normal tissue unharmed is improbable. The hope for a new generation of specifically targeted antitumor drugs may rest on the ability to identify tumor suppressor genes or oncogenes that play general roles in control of cell division.

The tumor suppressor genes which have been cloned and characterized influence susceptibility to: 1) Retinoblastoma (RB1); 2) Wilms' tumor (WT1); 3) Li-Fraumeni (TP53); 4) Familial adeno- matous polyposis (APC); 5) Neurofibromatosis type 1 (NF1); 6) Neurofibromatosis type 2 (NF2); 7) von Hippel-Lindau syndrome (VHL); 8) Multiple endocrine neoplasia type 2A (MEN2A); and 9) Melanoma (CDKN2).

Tumor suppressor loci that have been mapped genetically but not yet isolated include genes for: Multiple endocrine neoplasia type 1 (MEN1); Lynch cancer family syndrome 2 (LCFS2); Neuroblastoma (NB); Basal cell nevus syndrome (BCNS); Beckwith-Wiedemann syndrome (BWS); Renal cell carcinoma (RCC); Tuberous sclerosis 1 (TSC1); and Tuberous sclerosis 2 (TSC2). The tumor suppressor genes that have been characterized to date encode products with similarities to a variety of protein types, including DNA binding proteins (WT1), ancillary transcription regulators (RB1), GTPase activating proteins or GAPs (NF1), cytoskeletal components (NF2), membrane bound receptor kinases (MEN2A), cell cycle regulators (CDKN2) and others with no obvious similarity to known proteins (APC and VHL).

In many cases, the tumor suppressor gene originally identified through genetic studies has been shown to be lost or mutated in some sporadic tumors. This result suggests that regions of chromosomal aberration may signify the position of important tumor suppressor genes involved both in genetic predisposition to cancer and in sporadic cancer.

One of the hallmarks of several tumor suppressor genes characterized to date is that they are deleted at high frequency in certain tumor types. The deletions often involve loss of a single allele, a so-called loss of heterozygosity (LOH), but may also involve homozygous deletion of both alleles. For LOH, the remaining allele is presumed to be nonfunctional, either because of a preexisting inherited mutation, or because of a secondary sporadic mutation.

Breast cancer is one of the most significant diseases that affects women. At the current rate, American women have a 1 in 8 risk of developing breast cancer by age 95 (American Cancer Society, 1992). Treatment of breast cancer at later stages is often futile and disfiguring, making early detection a high priority in medical management of the disease. Ovarian cancer, although less frequent than breast cancer is often rapidly fatal and is the fourth most common cause of cancer mortality in American women. Genetic factors contribute to an ill-defined proportion of breast cancer incidence, estimated to be about 5% of all cases but approximately 25% of cases diagnosed before age 40 (Claus *et al.*, 1991). Breast cancer has been subdivided into two types, early-age onset and late-age onset, based on an inflection in the age-specific incidence curve around age 50. Mutation of one gene, BRCA1, is thought to account for approximately 45% of familial breast cancer, but at least 80% of families with both breast and ovarian cancer (Easton *et al.*, 1993).

Intense efforts to isolate the BRCA1 gene have proceeded since it was first mapped in 1990 (Hall *et al.*, 1990; Narod *et al.*, 1991). A second locus, BRCA2, has recently been mapped to chromosome 13q (Wooster *et al.*, 1994) and appears to account for a proportion of early-onset breast cancer roughly equal to BRCA1, but confers a lower risk of ovarian cancer. The remaining susceptibility to early-onset breast cancer is divided between as yet unmapped genes for familial cancer, and rarer germline mutations in genes such as TP53 (Malkin *et al.*, 1990). It has also been suggested that heterozygote carriers for defective forms of the Ataxia-Telangectasia gene are at higher risk for breast cancer (Swift *et al.*, 1976; Swift *et al.*, 1991). Late-age onset breast cancer is also often familial although the risks in relatives are not as high as those for early-onset breast cancer (Cannon-Albright *et al.*, 1994; Mettlin *et al.*, 1990). However, the percentage of such cases due to genetic susceptibility is unknown.

Breast cancer has long been recognized to be, in part, a familial disease (Anderson, 1972). Numerous investigators have examined the evidence for genetic inheritance and concluded that the data are most consistent with dominant inheritance for a major susceptibility locus or loci (Bishop

and Gardner, 1980; Go *et al.*, 1983; Willams and Anderson, 1984; Bishop *et al.*, 1988; Newman *et al.*, 1988; Claus *et al.*, 1991). Recent results demonstrate that at least three loci exist which convey susceptibility to breast cancer as well as other cancers. These loci are the TP53 locus on chromosome 17p (Malkin *et al.*, 1990), a 17q-linked susceptibility locus known as BRCA1 (Hall *et al.*, 1990), and one or more loci responsible for the unmapped residual. Hall *et al.* (1990) indicated that the inherited breast cancer susceptibility in kindreds with early age onset is linked to chromosome 17q21; although subsequent studies by this group using a more appropriate genetic model partially refuted the limitation to early onset breast cancer (Margaritte *et al.*, 1992).

Most strategies for cloning the 17q-linked breast cancer predisposing gene (BRCA1) require precise genetic localization studies. The simplest model for the functional role of BRCA1 holds that alleles of BRCA1 that predispose to cancer are recessive to wild type alleles; that is, cells that contain at least one wild type BRCA1 allele are not cancerous. However, cells that contain one wild type BRCA1 allele and one predisposing allele may occasionally suffer loss of the wild type allele either by random mutation or by chromosome loss during cell division (nondisjunction). All the progeny of such a mutant cell lack the wild type function of BRCA1 and may develop into tumors. According to this model, predisposing alleles of BRCA1 are recessive, yet susceptibility to cancer is inherited in a dominant fashion: women who possess one predisposing allele (and one wild type allele) risk developing cancer, because their mammary epithelial cells may spontaneously lose the wild type BRCA1 allele. This model applies to a group of cancer susceptibility loci known as tumor suppressors or antioncogenes, a class of genes that includes the retinoblastoma gene and neurofibromatosis gene. By inference this model may also explain the BRCA1 function, as has recently been suggested (Smith *et al.*, 1992).

A second possibility is that BRCA1 predisposing alleles are truly dominant; that is, a wild type allele of BRCA1 cannot overcome the tumor forming role of the predisposing allele. Thus, a cell that carries both wild type and mutant alleles would not necessarily lose the wild type copy of BRCA1 before giving rise to malignant cells. Instead, mammary cells in predisposed individuals would undergo some other stochastic change(s) leading to cancer.

If BRCA1 predisposing alleles are recessive, the BRCA1 gene is expected to be expressed in normal mammary tissue but not functionally expressed in mammary tumors. In contrast, if BRCA1 predisposing alleles are dominant, the wild type BRCA1 gene may or may not be expressed in

normal mammary tissue. However, the predisposing allele will likely be expressed in breast tumor cells.

The 17q linkage of BRCA1 was independently confirmed in three of five kindreds with both breast cancer and ovarian cancer (Narod *et al.*, 1991). These studies claimed to localize the gene within a very large region, 15 centiMorgans (cM), or approximately 15 million base pairs, to either side of the linked marker pCMM86 (D17S74). However, attempts to define the region further by genetic studies, using markers surrounding pCMMS6, proved unsuccessful. Subsequent studies indicated that the gene was considerably more proximal (Easton *et al.*, 1993) and that the original analysis was flawed (Margaritte *et al.*, 1992). Hall *et al.*, (1992) recently localized the BRCA1 gene to an approximately 8 cM interval (approximately 8 million base pairs) bounded by Mfd15 (D17S250) on the proximal side and the human GIP gene on the distal side. A slightly narrower interval for the BRCA1 locus, based on publicly available data, was agreed upon at the Chromosome 17 workshop in March of 1992 (Fain, 1992). The size of these regions and the uncertainty associated with them has made it exceedingly difficult to design and implement physical mapping and/or cloning strategies for isolating the BRCA1 gene.

Identification of a breast cancer susceptibility locus would permit the early detection of susceptible individuals and greatly increase our ability to understand the initial steps which lead to cancer. As susceptibility loci are often altered during tumor progression, cloning these genes could also be important in the development of better diagnostic and prognostic products, as well as better cancer therapies.

SUMMARY OF THE INVENTION

The present invention relates generally to the field of human genetics. Specifically, the present invention relates to methods and materials used to isolate and detect a human breast cancer predisposing gene (BRCA1), some alleles of which cause susceptibility to cancer, in particular breast and ovarian cancer. More specifically, the present invention relates to germline mutations in the BRCA1 gene and their use in the diagnosis of predisposition to breast and ovarian cancer. The invention further relates to somatic mutations in the BRCA1 gene in human breast cancer and their use in the diagnosis and prognosis of human breast and ovarian cancer. Additionally, the invention relates to somatic mutations in the BRCA1 gene in other human cancers and their use in the

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diagnosis and prognosis of human cancers. The invention also relates to the therapy of human cancers which have a mutation in the BRCA1 gene, including gene therapy, protein replacement therapy and protein mimetics. The invention further relates to the screening of drugs for cancer therapy. Finally, the invention relates to the screening of the BRCA1 gene for mutations, which
5 are useful for diagnosing the predisposition to breast and ovarian cancer.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram showing the order of loci neighboring BRCA1 as determined by the
10 chromosome 17 workshop. Figure 1 is reproduced from Fain, 1992.

Figure 2 is a schematic map of YACs which define part of Mfd15-Mfd188 region.

Figure 3 is a schematic map of STSs, PIs and BACs in the BRCA1 region.

Figure 4 is a schematic map of human chromosome 17. The pertinent region containing
BRCA1 is expanded to indicate the relative positions of two previously identified genes, CA125
15 and RNU2, BRCA1 spans the marker D17S855.

Figure 5 shows alignment of the BRCA1 zinc-finger domain with 3 other zinc-finger
domains that scored highest in a Smith-Waterman alignment. RPT1 encodes a protein that appears
to be a negative regulator of the IL-2 receptor in mouse. RIN1 encodes a DNA-binding protein
that includes a RING-finger motif related to the zinc-finger. RFP1 encodes a putative transcription
20 factor that is the N-terminal domain of the RET oncogene product. The bottom line contains the
C3HC4 consensus zinc-finger sequence showing the positions of cysteines and one histidine that
form the zinc ion binding pocket.

Figure 6 is a diagram of BRCA1 mRNA showing the locations of introns and the variants of
BRCA1 mRNA produced by alternative splicing. Intron locations are shown by dark triangles and
the exons are numbered below the line representing the cDNA. The top cDNA is the composite
25 used to generate the peptide sequence of BRCA1. Alternative forms identified as cDNA clones or
hybrid selection clones are shown below.

Figure 7 shows the tissue expression pattern of BRCA1. The blot was obtained from
Clontech and contains RNA from the indicated tissues. Hybridization conditions were as
30 recommended by the manufacturer using a probe consisting of nucleotide positions 3631 to 3930

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of BRCA1. Note that both breast and ovary are heterogeneous tissues and the percentage of relevant epithelial cells can be variable. Molecular weight standards are in kilobases.

Figure 8 is a diagram of the 5' untranslated region plus the beginning of the translated region of BRCA1 showing the locations of introns and the variants of BRCA1 mRNA produced by alternative splicing. Intron locations are shown by broken dashed lines. Six alternate splice forms are shown.

Figure 9A shows a nonsense mutation in Kindred 2082. P indicates the person originally screened, b and c are haplotype carriers, a, d, e, f, and g do not carry the BRCA1 haplotype. The C to T mutation results in a stop codon and creates a site for the restriction enzyme *AvrII*. PCR amplification products are cut with this enzyme. The carriers are heterozygous for the site and therefore show three bands. Non-carriers remain uncut.

Figure 9B shows a mutation and cosegregation analysis in BRCA1 kindreds. Carrier individuals are represented as filled circles and squares in the pedigree diagrams. Frameshift mutation in Kindred 1910. The first three lanes are control, noncarrier samples. Lanes labeled 1-3 contain sequences from carrier individuals. Lane 4 contains DNA from a kindred member who does not carry the BRCA1 mutation. The diamond is used to prevent identification of the kindred. The frameshift resulting from the additional C is apparent in lanes labeled 1, 2, and 3.

Figure 9C shows a mutation and cosegregation analysis in BRCA1 kindreds. Carrier individuals are represented as filled circles and squares in the pedigree diagrams. Inferred regulatory mutation in Kindred 2035. ASO analysis of carriers and noncarriers of 2 different polymorphisms (PM1 and PM7) which were examined for heterozygosity in the germline and compared to the heterozygosity of lymphocyte mRNA. The top 2 rows of each panel contain PCR products amplified from genomic DNA and the bottom 2 rows contain PCR products amplified from cDNA. "A" and "G" are the two alleles detected by the ASO. The dark spots indicate that a particular allele is present in the sample. The first three lanes of PM7 represent the three genotypes in the general population.

Figures 10A-10H show genomic sequence of BRCA1. The lower case letters denote intron sequence while the upper case letters denote exon sequence. Indefinite intervals within introns are designated with vvvvvvvvvvvv. Known polymorphic sites are shown as underlined and boldface type.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates generally to the field of human genetics. Specifically, the present invention relates to methods and materials used to isolate and detect a human breast cancer predisposing gene (BRCA1), some alleles of which cause susceptibility to cancer, in particular breast and ovarian cancer. More specifically, the present invention relates to germline mutations in the BRCA1 gene and their use in the diagnosis of predisposition to breast and ovarian cancer. The invention further relates to somatic mutations in the BRCA1 gene in human breast cancer and their use in the diagnosis and prognosis of human breast and ovarian cancer. Additionally, the invention relates to somatic mutations in the BRCA1 gene in other human cancers and their use in the diagnosis and prognosis of human cancers. The invention also relates to the therapy of human cancers which have a mutation in the BRCA1 gene, including gene therapy, protein replacement therapy and protein mimetics. The invention further relates to the screening of drugs for cancer therapy. Finally, the invention relates to the screening of the BRCA1 gene for mutations, which are useful for diagnosing the predisposition to breast and ovarian cancer.

The present invention provides an isolated polynucleotide comprising all, or a portion of the BRCA1 locus or of a mutated BRCA1 locus, preferably at least eight bases and not more than about 100 kb in length. Such polynucleotides may be antisense polynucleotides. The present invention also provides a recombinant construct comprising such an isolated polynucleotide, for example, a recombinant construct suitable for expression in a transformed host cell.

Also provided by the present invention are methods of detecting a polynucleotide comprising a portion of the BRCA1 locus or its expression product in an analyte. Such methods may further comprise the step of amplifying the portion of the BRCA1 locus, and may further include a step of providing a set of polynucleotides which are primers for amplification of said portion of the BRCA1 locus. The method is useful for either diagnosis of the predisposition to cancer or the diagnosis or prognosis of cancer.

The present invention also provides isolated antibodies, preferably monoclonal antibodies, which specifically bind to an isolated polypeptide comprised of at least five amino acid residues encoded by the BRCA1 locus.

The present invention also provides kits for detecting in an analyte a polynucleotide comprising a portion of the BRCA1 locus, the kits comprising a polynucleotide complementary to the portion of the BRCA1 locus packaged in a suitable container, and instructions for its use.

5 The present invention further provides methods of preparing a polynucleotide comprising polymerizing nucleotides to yield a sequence comprised of at least eight consecutive nucleotides of the BRCA1 locus; and methods of preparing a polypeptide comprising polymerizing amino acids to yield a sequence comprising at least five amino acids encoded within the BRCA1 locus.

10 The present invention further provides methods of screening the BRCA1 gene to identify mutations. Such methods may further comprise the step of amplifying a portion of the BRCA1 locus, and may further include a step of providing a set of polynucleotides which are primers for amplification of said portion of the BRCA1 locus. The method is useful for identifying mutations for use in either diagnosis of the predisposition to cancer or the diagnosis or prognosis of cancer.

The present invention further provides methods of screening suspected BRCA1 mutant alleles to identify mutations in the BRCA1 gene.

15 In addition, the present invention provides methods of screening drugs for cancer therapy to identify suitable drugs for restoring BRCA1 gene product function.

20 Finally, the present invention provides the means necessary for production of gene-based therapies directed at cancer cells. These therapeutic agents may take the form of polynucleotides comprising all or a portion of the BRCA1 locus placed in appropriate vectors or delivered to target cells in more direct ways such that the function of the BRCA1 protein is reconstituted. Therapeutic agents may also take the form of polypeptides based on either a portion of, or the entire protein sequence of BRCA1. These may functionally replace the activity of BRCA1 *in vivo*.

25 It is a discovery of the present invention that the BRCA1 locus which predisposes individuals to breast cancer and ovarian cancer, is a gene encoding a BRCA1 protein, which has been found to have no significant homology with known protein or DNA sequences. This gene is termed BRCA1 herein. It is a discovery of the present invention that mutations in the BRCA1 locus in the germline are indicative of a predisposition to breast cancer and ovarian cancer. Finally, it is a discovery of the present invention that somatic mutations in the BRCA1 locus are also associated with breast cancer, ovarian cancer and other cancers, which represents an indicator of
30 these cancers or of the prognosis of these cancers. The mutational events of the BRCA1 locus can

involve deletions, insertions and point mutations within the coding sequence and the non-coding sequence.

Starting from a region on the long arm of human chromosome 17 of the human genome, 17q, which has a size estimated at about 8 million base pairs, a region which contains a genetic locus, BRCA1, which causes susceptibility to cancer, including breast and ovarian cancer, has been identified.

The region containing the BRCA1 locus was identified using a variety of genetic techniques. Genetic mapping techniques initially defined the BRCA1 region in terms of recombination with genetic markers. Based upon studies of large extended families ("kindreds") with multiple cases of breast cancer (and ovarian cancer cases in some kindreds), a chromosomal region has been pinpointed that contains the BRCA1 gene as well as other putative susceptibility alleles in the BRCA1 locus. Two meiotic breakpoints have been discovered on the distal side of the BRCA1 locus which are expressed as recombinants between genetic markers and the disease, and one recombinant on the proximal side of the BRCA1 locus. Thus, a region which contains the BRCA1 locus is physically bounded by these markers.

The use of the genetic markers provided by this invention allowed the identification of clones which cover the region from a human yeast artificial chromosome (YAC) or a human bacterial artificial chromosome (BAC) library. It also allowed for the identification and preparation of more easily manipulated cosmid, P1 and BAC clones from this region and the construction of a contig from a subset of the clones. These cosmids, P1s, YACs and BACs provide the basis for cloning the BRCA1 locus and provide the basis for developing reagents effective, for example, in the diagnosis and treatment of breast and/or ovarian cancer. The BRCA1 gene and other potential susceptibility genes have been isolated from this region. The isolation was done using software trapping (a computational method for identifying sequences likely to contain coding exons, from contiguous or discontinuous genomic DNA sequences), hybrid selection techniques and direct screening, with whole or partial cDNA inserts from cosmids, P1s and BACs, in the region to screen cDNA libraries. These methods were used to obtain sequences of loci expressed in breast and other tissue. These candidate loci were analyzed to identify sequences which confer cancer susceptibility. We have discovered that there are mutations in the coding sequence of the BRCA1 locus in kindreds which are responsible for the 17q-linked cancer susceptibility known as BRCA1. This gene was not known to be in this region. The present invention not only facilitates

the early detection of certain cancers, so vital to patient survival, but also permits the detection of susceptible individuals before they develop cancer.

Population Resources

5 Large, well-documented Utah kindreds are especially important in providing good resources for human genetic studies. Each large kindred independently provides the power to detect whether a BRCA1 susceptibility allele is segregating in that family. Recombinants informative for localization and isolation of the BRCA1 locus could be obtained only from kindreds large enough to confirm the presence of a susceptibility allele. Large sibships are especially important for
10 studying breast cancer, since penetrance of the BRCA1 susceptibility allele is reduced both by age and sex, making informative sibships difficult to find. Furthermore, large sibships are essential for constructing haplotypes of deceased individuals by inference from the haplotypes of their close relatives.

 While other populations may also provide beneficial information, such studies generally
15 require much greater effort, and the families are usually much smaller and thus less informative. Utah's age-adjusted breast cancer incidence is 20% lower than the average U.S. rate. The lower incidence in Utah is probably due largely to an early age at first pregnancy, increasing the probability that cases found in Utah kindreds carry a genetic predisposition.

20 Genetic Mapping

 Given a set of informative families, genetic markers are essential for linking a disease to a region of a chromosome. Such markers include restriction fragment length polymorphisms (RFLPs) (Botstein *et al.*, 1980), markers with a variable number of tandem repeats (VNTRs) (Jeffreys *et al.*, 1985; Nakamura *et al.*, 1987), and an abundant class of DNA polymorphisms based
25 on short tandem repeats (STRs), especially repeats of CpA (Weber and May, 1989; Litt *et al.*, 1989). To generate a genetic map, one selects potential genetic markers and tests them using DNA extracted from members of the kindreds being studied.

 Genetic markers useful in searching for a genetic locus associated with a disease can be selected on an *ad hoc* basis, by densely covering a specific chromosome, or by detailed analysis of
30 a specific region of a chromosome. A preferred method for selecting genetic markers linked with a disease involves evaluating the degree of informativeness of kindreds to determine the ideal

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distance between genetic markers of a given degree of polymorphism, then selecting markers from known genetic maps which are ideally spaced for maximal efficiency. Informativeness of kindreds is measured by the probability that the markers will be heterozygous in unrelated individuals. It is also most efficient to use STR markers which are detected by amplification of the target nucleic acid sequence using PCR; such markers are highly informative, easy to assay (Weber and May, 1989), and can be assayed simultaneously using multiplexing strategies (Skolnick and Wallace, 1988), greatly reducing the number of experiments required.

Once linkage has been established, one needs to find markers that flank the disease locus, i.e., one or more markers proximal to the disease locus, and one or more markers distal to the disease locus. Where possible, candidate markers can be selected from a known genetic map. Where none is known, new markers can be identified by the STR technique, as shown in the Examples.

Genetic mapping is usually an iterative process. In the present invention, it began by defining flanking genetic markers around the BRCA1 locus, then replacing these flanking markers with other markers that were successively closer to the BRCA1 locus. As an initial step, recombination events, defined by large extended kindreds, helped specifically to localize the BRCA1 locus as either distal or proximal to a specific genetic marker (Goldgar *et al.*, 1994).

The region surrounding BRCA1, until the disclosure of the present invention, was not well mapped and there were few markers. Therefore, short repetitive sequences on cosmids subcloned from YACs, which had been physically mapped, were analyzed in order to develop new genetic markers. Using this approach, one marker of the present invention, 42D6, was discovered which replaced pCMM86 as the distal flanking marker for the BRCA1 region. Since 42D6 is approximately 14 cM from pCMM86, the BRCA1 region was thus reduced by approximately 14 centiMorgans (Easton *et al.*, 1993). The present invention thus began by finding a much more closely linked distal flanking marker of the BRCA1 region. BRCA1 was then discovered to be distal to the genetic marker Mfd15. Therefore, BRCA1 was shown to be in a region of 6 to 10 million bases bounded by Mfd15 and 42D6. Marker Mfd191 was subsequently discovered to be distal to Mfd15 and proximal to BRCA1. Thus, Mfd15 was replaced with Mfd191 as the closest proximal genetic marker. Similarly, it was discovered that genetic marker Mfd188 could replace genetic marker 42D6, narrowing the region containing the BRCA1 locus to approximately 1.5 million bases. Then the marker Mfd191 was replaced with tdj1474 as the proximal marker and

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MfdI88 was replaced with U5R as the distal marker, further narrowing the BRCA1 region to a small enough region to allow isolation and characterization of the BRCA1 locus (see Figure 3), using techniques known in the art and described herein.

5 Physical Mapping

Three distinct methods were employed to physically map the region. The first was the use of yeast artificial chromosomes (YACs) to clone the region which is flanked by tdj1474 and U5R. The second was the creation of a set of P1, BAC and cosmid clones which cover the region containing the BRCA1 locus.

10 Yeast Artificial Chromosomes (YACs). Once a sufficiently small region containing the BRCA1 locus was identified, physical isolation of the DNA in the region proceeded by identifying a set of overlapping YACs which covers the region. Useful YACs can be isolated from known libraries, such as the St. Louis and CEPH YAC libraries, which are widely distributed and contain approximately 50,000 YACs each. The YACs isolated were from these publicly accessible
15 libraries and can be obtained from a number of sources including the Michigan Genome Center. Clearly, others who had access to these YACs, without the disclosure of the present invention, would not have known the value of the specific YACs we selected since they would not have known which YACs were within, and which YACs outside of, the smallest region containing the BRCA1 locus.

20 Cosmid, P1 and BAC Clones. In the present invention, it is advantageous to proceed by obtaining cosmid, P1, and BAC clones to cover this region. The smaller size of these inserts, compared to YAC inserts, makes them more useful as specific hybridization probes. Furthermore, having the cloned DNA in bacterial cells, rather than in yeast cells, greatly increases the ease with which the DNA of interest can be manipulated, and improves the signal-to-noise ratio of
25 hybridization assays. For cosmid subclones of YACs, the DNA is partially digested with the restriction enzyme Sau3A and cloned into the BamHI site of the pWE15 cosmid vector (Stratagene, cat. #1251201). The cosmids containing human sequences are screened by hybridization with human repetitive DNA (e.g., Gibco/BRL, Human C₆t-1 DNA, cat. 5279SA), and then fingerprinted by a variety of techniques, as detailed in the Examples.

P1 and BAC clones are obtained by screening libraries constructed from the total human genome with specific sequence tagged sites (STSs) derived from the YACs, cosmids or P1s and BACs, isolated as described herein.

These P1, BAC and cosmid clones can be compared by interspersed repetitive sequence (IRS) PCR and/or restriction enzyme digests followed by gel electrophoresis and comparison of the resulting DNA fragments ("fingerprints") (Maniatis *et al.*, 1982). The clones can also be characterized by the presence of STSs. The fingerprints are used to define an overlapping contiguous set of clones which covers the region but is not excessively redundant, referred to herein as a "minimum tiling path". Such a minimum tiling path forms the basis for subsequent experiments to identify cDNAs which may originate from the BRCA1 locus.

Coverage of the Gap with P1 and BAC Clones. To cover any gaps in the BRCA1 contig between the identified cosmids with genomic clones, clones in P1 and BAC vectors which contain inserts of genomic DNA roughly twice as large as cosmids for P1s and still greater for BACs (Sternberg, 1990; Sternberg *et al.*, 1990; Pierce *et al.*, 1992; Shizuya *et al.*, 1992) were used. P1 clones were isolated by Genome Sciences using PCR primers provided by us for screening. BACs were provided by hybridization techniques in Dr. Mel Simon's laboratory. The strategy of using P1 clones also permitted the covering of the genomic region with an independent set of clones not derived from YACs. This guards against the possibility of other deletions in YACs that have not been detected. These new sequences derived from the P1 clones provide the material for further screening for candidate genes, as described below.

Gene Isolation.

There are many techniques for testing genomic clones for the presence of sequences likely to be candidates for the coding sequence of a locus one is attempting to isolate, including but not limited to:

- a. zoo blots
- b. identifying HTF islands
- c. exon trapping
- d. hybridizing cDNA to cosmids or YACs.
- e. screening cDNA libraries.

(a) Zoo blots. The first technique is to hybridize cosmids to Southern blots to identify DNA sequences which are evolutionarily conserved, and which therefore give positive hybridization signals with DNA from species of varying degrees of relationship to humans (such as monkey, cow, chicken, pig, mouse and rat). Southern blots containing such DNA from a variety of species are commercially available (Clontech, Cat. 7753-1).

(b) Identifying HTF islands. The second technique involves finding regions rich in the nucleotides C and G, which often occur near or within coding sequences. Such sequences are called HTF (HpaI tiny fragment) or CpG islands, as restriction enzymes specific for sites which contain CpG dimers cut frequently in these regions (Lindsay *et al.*, 1987).

(c) Exon trapping. The third technique is exon trapping, a method that identifies sequences in genomic DNA which contain splice junctions and therefore are likely to comprise coding sequences of genes. Exon amplification (Buckler *et al.*, 1991) is used to select and amplify exons from DNA clones described above. Exon amplification is based on the selection of RNA sequences which are flanked by functional 5' and/or 3' splice sites. The products of the exon amplification are used to screen the breast cDNA libraries to identify a manageable number of candidate genes for further study. Exon trapping can also be performed on small segments of sequenced DNA using computer programs or by software trapping.

(d) Hybridizing cDNA to Cosmids, PIs, BACs or YACs. The fourth technique is a modification of the selective enrichment technique which utilizes hybridization of cDNA to cosmids, PIs, BACs or YACs and permits transcribed sequences to be identified in, and recovered from cloned genomic DNA (Kandpal *et al.*, 1990). The selective enrichment technique, as modified for the present purpose, involves binding DNA from the region of BRCA1 present in a YAC to a column matrix and selecting cDNAs from the relevant libraries which hybridize with the bound DNA, followed by amplification and purification of the bound DNA, resulting in a great enrichment for cDNAs in the region represented by the cloned genomic DNA.

(e) Identification of cDNAs. The fifth technique is to identify cDNAs that correspond to the BRCA1 locus. Hybridization probes containing putative coding sequences, selected using any of the above techniques, are used to screen various libraries, including breast tissue cDNA libraries, ovarian cDNA libraries, and any other necessary libraries.

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Another variation on the theme of direct selection of cDNA was also used to find candidate genes for BRCA1 (Lovett *et al.*, 1991; Futreal, 1993). This method uses cosmid, P1 or BAC DNA as the probe. The probe DNA is digested with a blunt cutting restriction enzyme such as HaeIII. Double stranded adapters are then ligated onto the DNA and serve as binding sites for primers in subsequent PCR amplification reactions using biotinylated primers. Target cDNA is generated from mRNA derived from tissue samples, e.g., breast tissue, by synthesis of either random primed or oligo(dT) primed first strand followed by second strand synthesis. The cDNA ends are rendered blunt and ligated onto double-stranded adapters. These adapters serve as amplification sites for PCR. The target and probe sequences are denatured and mixed with human C₀t-1 DNA to block repetitive sequences. Solution hybridization is carried out to high C₀t-1/2 values to ensure hybridization of rare target cDNA molecules. The annealed material is then captured on avidin beads, washed at high stringency and the retained cDNAs are eluted and amplified by PCR. The selected cDNA is subjected to further rounds of enrichment before cloning into a plasmid vector for analysis.

Testing the cDNA for Candidacy

Proof that the cDNA is the BRCA1 locus is obtained by finding sequences in DNA extracted from affected kindred members which create abnormal BRCA1 gene products or abnormal levels of BRCA1 gene product. Such BRCA1 susceptibility alleles will co-segregate with the disease in large kindreds. They will also be present at a much higher frequency in non-kindred individuals with breast and ovarian cancer than in individuals in the general population. Finally, since tumors often mutate somatically at loci which are in other instances mutated in the germline, we expect to see normal germline BRCA1 alleles mutated into sequences which are identical or similar to BRCA1 susceptibility alleles in DNA extracted from tumor tissue. Whether one is comparing BRCA1 sequences from tumor tissue to BRCA1 alleles from the germline of the same individuals, or one is comparing germline BRCA1 alleles from cancer cases to those from unaffected individuals, the key is to find mutations which are serious enough to cause obvious disruption to the normal function of the gene product. These mutations can take a number of forms. The most severe forms would be frame shift mutations or large deletions which would cause the gene to code for an abnormal protein or one which would significantly alter protein expression. Less severe disruptive mutations would include small in-frame deletions and nonconservative base pair

substitutions which would have a significant effect on the protein produced, such as changes to or from a cysteine residue, from a basic to an acidic amino acid or vice versa, from a hydrophobic to hydrophilic amino acid or vice versa, or other mutations which would affect secondary, tertiary or quaternary protein structure. Silent mutations or those resulting in conservative amino acid substitutions would not generally be expected to disrupt protein function.

According to the diagnostic and prognostic method of the present invention, alteration of the wild-type BRCA1 locus is detected. In addition, the method can be performed by detecting the wild-type BRCA1 locus and confirming the lack of a predisposition to cancer at the BRCA1 locus. "Alteration of a wild-type gene" encompasses all forms of mutations including deletions, insertions and point mutations in the coding and noncoding regions. Deletions may be of the entire gene or of only a portion of the gene. Point mutations may result in stop codons, frameshift mutations or amino acid substitutions. Somatic mutations are those which occur only in certain tissues, e.g., in the tumor tissue, and are not inherited in the germline. Germline mutations can be found in any of a body's tissues and are inherited. If only a single allele is somatically mutated, an early neoplastic state is indicated. However, if both alleles are somatically mutated, then a late neoplastic state is indicated. The finding of BRCA1 mutations thus provides both diagnostic and prognostic information. A BRCA1 allele which is not deleted (e.g., found on the sister chromosome to a chromosome carrying a BRCA1 deletion) can be screened for other mutations, such as insertions, small deletions, and point mutations. It is believed that many mutations found in tumor tissues will be those leading to decreased expression of the BRCA1 gene product. However, mutations leading to non-functional gene products would also lead to a cancerous state. Point mutational events may occur in regulatory regions, such as in the promoter of the gene, leading to loss or diminution of expression of the mRNA. Point mutations may also abolish proper RNA processing, leading to loss of expression of the BRCA1 gene product, or to a decrease in mRNA stability or translation efficiency.

Useful diagnostic techniques include, but are not limited to fluorescent *in situ* hybridization (FISH), direct DNA sequencing, PFGE analysis, Southern blot analysis, single stranded conformation analysis (SSCA), RNase protection assay, allele-specific oligonucleotide (ASO), dot blot analysis and PCR-SSCP, as discussed in detail further below.

Predisposition to cancers, such as breast and ovarian cancer, and the other cancers identified herein, can be ascertained by testing any tissue of a human for mutations of the BRCA1 gene. For

example, a person who has inherited a germline BRCA1 mutation would be prone to develop cancers. This can be determined by testing DNA from any tissue of the person's body. Most simply, blood can be drawn and DNA extracted from the cells of the blood. In addition, prenatal diagnosis can be accomplished by testing fetal cells, placental cells or amniotic cells for mutations
5 of the BRCA1 gene. Alteration of a wild-type BRCA1 allele, whether, for example, by point mutation or deletion, can be detected by any of the means discussed herein.

There are several methods that can be used to detect DNA sequence variation. Direct DNA sequencing, either manual sequencing or automated fluorescent sequencing can detect sequence variation. For a gene as large as BRCA1, manual sequencing is very labor-intensive, but under
10 optimal conditions, mutations in the coding sequence of a gene are rarely missed. Another approach is the single-stranded conformation polymorphism assay (SSCA) (Orita *et al.*, 1989). This method does not detect all sequence changes, especially if the DNA fragment size is greater than 200 bp, but can be optimized to detect most DNA sequence variation. The reduced detection sensitivity is a disadvantage, but the increased throughput possible with SSCA makes it an
15 attractive, viable alternative to direct sequencing for mutation detection on a research basis. The fragments which have shifted mobility on SSCA gels are then sequenced to determine the exact nature of the DNA sequence variation. Other approaches based on the detection of mismatches between the two complementary DNA strands include clamped denaturing gel electrophoresis (CDGE) (Sheffield *et al.*, 1991), heteroduplex analysis (HA) (White *et al.*, 1992) and chemical
20 mismatch cleavage (CMC) (Grompe *et al.*, 1989). None of the methods described above will detect large deletions, duplications or insertions, nor will they detect a regulatory mutation which affects transcription or translation of the protein. Other methods which might detect these classes of mutations such as a protein truncation assay or the asymmetric assay, detect only specific types of mutations and would not detect missense mutations. A review of currently available methods of
25 detecting DNA sequence variation can be found in a recent review by Grompe (1993). Once a mutation is known, an allele specific detection approach such as allele specific oligonucleotide (ASO) hybridization can be utilized to rapidly screen large numbers of other samples for that same mutation.

In order to detect the alteration of the wild-type BRCA1 gene in a tissue, it is helpful to
30 isolate the tissue free from surrounding normal tissues. Means for enriching tissue preparation for tumor cells are known in the art. For example, the tissue may be isolated from paraffin or cryostat

sections. Cancer cells may also be separated from normal cells by flow cytometry. These techniques, as well as other techniques for separating tumor cells from normal cells, are well known in the art. If the tumor tissue is highly contaminated with normal cells, detection of mutations is more difficult.

5 A rapid preliminary analysis to detect polymorphisms in DNA sequences can be performed by looking at a series of Southern blots of DNA cut with one or more restriction enzymes, preferably with a large number of restriction enzymes. Each blot contains a series of normal individuals and a series of cancer cases, tumors, or both. Southern blots displaying hybridizing fragments (differing in length from control DNA when probed with sequences near or including
10 the BRCA1 locus) indicate a possible mutation. If restriction enzymes which produce very large restriction fragments are used, then pulsed field gel electrophoresis (PFGE) is employed.

Detection of point mutations may be accomplished by molecular cloning of the BRCA1 allele(s) and sequencing the allele(s) using techniques well known in the art. Alternatively, the gene sequences can be amplified directly from a genomic DNA preparation from the tumor tissue,
15 using known techniques. The DNA sequence of the amplified sequences can then be determined.

There are six well known methods for a more complete, yet still indirect, test for confirming the presence of a susceptibility allele: 1) single stranded conformation analysis (SSCA) (Orita *et al.*, 1989); 2) denaturing gradient gel electrophoresis (DGGE) (Wartell *et al.*, 1990; Sheffield *et al.*, 1989); 3) RNase protection assays (Finkelstein *et al.*, 1990; Kinszler *et al.*, 1991); 4) allele-specific
20 oligonucleotides (ASOs) (Conner *et al.*, 1983); 5) the use of proteins which recognize nucleotide mismatches, such as the *E. coli* mutS protein (Modrich, 1991); and 6) allele-specific PCR (Rano & Kidd, 1989). For allele-specific PCR, primers are used which hybridize at their 3' ends to a particular BRCA1 mutation. If the particular BRCA1 mutation is not present, an amplification product is not observed. Amplification Refractory Mutation System (ARMS) can also be used, as
25 disclosed in European Patent Application Publication No. 0332435 and in Newton *et al.*, 1989. Insertions and deletions of genes can also be detected by cloning, sequencing and amplification. In addition, restriction fragment length polymorphism (RFLP) probes for the gene or surrounding marker genes can be used to score alteration of an allele or an insertion in a polymorphic fragment.

Such a method is particularly useful for screening relatives of an affected individual for the
30 presence of the BRCA1 mutation found in that individual. Other techniques for detecting insertions and deletions as known in the art can be used.

In the first three methods (SSCA, DGGE and RNase protection assay), a new electrophoretic band appears. SSCA detects a band which migrates differentially because the sequence change causes a difference in single-strand, intramolecular base pairing. RNase protection involves cleavage of the mutant polynucleotide into two or more smaller fragments. DGGE detects differences in migration rates of mutant sequences compared to wild-type sequences, using a denaturing gradient gel. In an allele-specific oligonucleotide assay, an oligonucleotide is designed which detects a specific sequence, and the assay is performed by detecting the presence or absence of a hybridization signal. In the mutS assay, the protein binds only to sequences that contain a nucleotide mismatch in a heteroduplex between mutant and wild-type sequences.

Mismatches, according to the present invention, are hybridized nucleic acid duplexes in which the two strands are not 100% complementary. Lack of total homology may be due to deletions, insertions, inversions or substitutions. Mismatch detection can be used to detect point mutations in the gene or in its mRNA product. While these techniques are less sensitive than sequencing, they are simpler to perform on a large number of tumor samples. An example of a mismatch cleavage technique is the RNase protection method. In the practice of the present invention, the method involves the use of a labeled riboprobe which is complementary to the human wild-type BRCA1 gene coding sequence. The riboprobe and either mRNA or DNA isolated from the tumor tissue are annealed (hybridized) together and subsequently digested with the enzyme RNase A which is able to detect some mismatches in a duplex RNA structure. If a mismatch is detected by RNase A, it cleaves at the site of the mismatch. Thus, when the annealed RNA preparation is separated on an electrophoretic gel matrix, if a mismatch has been detected and cleaved by RNase A, an RNA product will be seen which is smaller than the full length duplex RNA for the riboprobe and the mRNA or DNA. The riboprobe need not be the full length of the BRCA1 mRNA or gene but can be a segment of either. If the riboprobe comprises only a segment of the BRCA1 mRNA or gene, it will be desirable to use a number of these probes to screen the whole mRNA sequence for mismatches.

In similar fashion, DNA probes can be used to detect mismatches, through enzymatic or chemical cleavage. See, e.g., Cotton *et al.*, 1988; Shenk *et al.*, 1975; Novack *et al.*, 1986. Alternatively, mismatches can be detected by shifts in the electrophoretic mobility of mismatched duplexes relative to matched duplexes. See, e.g., Cariello, 1988. With either riboprobes or DNA probes, the cellular mRNA or DNA which might contain a mutation can be amplified using PCR

(see below) before hybridization. Changes in DNA of the BRCA1 gene can also be detected using Southern hybridization, especially if the changes are gross rearrangements, such as deletions and insertions.

DNA sequences of the BRCA1 gene which have been amplified by use of PCR may also be screened using allele-specific probes. These probes are nucleic acid oligomers, each of which contains a region of the BRCA1 gene sequence harboring a known mutation. For example, one oligomer may be about 30 nucleotides in length, corresponding to a portion of the BRCA1 gene sequence. By use of a battery of such allele-specific probes, PCR amplification products can be screened to identify the presence of a previously identified mutation in the BRCA1 gene.

Hybridization of allele-specific probes with amplified BRCA1 sequences can be performed, for example, on a nylon filter. Hybridization to a particular probe under stringent hybridization conditions indicates the presence of the same mutation in the tumor tissue as in the allele-specific probe.

The most definitive test for mutations in a candidate locus is to directly compare genomic BRCA1 sequences from cancer patients with those from a control population. Alternatively, one could sequence messenger RNA after amplification, e.g., by PCR, thereby eliminating the necessity of determining the exon structure of the candidate gene.

Mutations from cancer patients falling outside the coding region of BRCA1 can be detected by examining the non-coding regions, such as introns and regulatory sequences near or within the BRCA1 gene. An early indication that mutations in noncoding regions are important may come from Northern blot experiments that reveal messenger RNA molecules of abnormal size or abundance in cancer patients as compared to control individuals.

Alteration of BRCA1 mRNA expression can be detected by any techniques known in the art. These include Northern blot analysis, PCR amplification and RNase protection. Diminished mRNA expression indicates an alteration of the wild-type BRCA1 gene. Alteration of wild-type BRCA1 genes can also be detected by screening for alteration of wild-type BRCA1 protein. For example, monoclonal antibodies immunoreactive with BRCA1 can be used to screen a tissue. Lack of cognate antigen would indicate a BRCA1 mutation. Antibodies specific for products of mutant alleles could also be used to detect mutant BRCA1 gene product. Such immunological assays can be done in any convenient formats known in the art. These include Western blots, immunohistochemical assays and ELISA assays. Any means for detecting an altered BRCA1

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protein can be used to detect alteration of wild-type BRCA1 genes. Functional assays, such as protein binding determinations, can be used. In addition, assays can be used which detect BRCA1 biochemical function. Finding a mutant BRCA1 gene product indicates alteration of a wild-type BRCA1 gene.

5 Mutant BRCA1 genes or gene products can also be detected in other human body samples, such as serum, stool, urine and sputum. The same techniques discussed above for detection of mutant BRCA1 genes or gene products in tissues can be applied to other body samples. Cancer cells are sloughed off from tumors and appear in such body samples. In addition, the BRCA1 gene product itself may be secreted into the extracellular space and found in these body samples even in
10 the absence of cancer cells. By screening such body samples, a simple early diagnosis can be achieved for many types of cancers. In addition, the progress of chemotherapy or radiotherapy can be monitored more easily by testing such body samples for mutant BRCA1 genes or gene products.

 The methods of diagnosis of the present invention are applicable to any tumor in which BRCA1 has a role in tumorigenesis. The diagnostic method of the present invention is useful for
15 clinicians, so they can decide upon an appropriate course of treatment.

 The primer pairs of the present invention are useful for determination of the nucleotide sequence of a particular BRCA1 allele using PCR. The pairs of single-stranded DNA primers can be annealed to sequences within or surrounding the BRCA1 gene on chromosome 17q21 in order to prime amplifying DNA synthesis of the BRCA1 gene itself. A complete set of these primers
20 allows synthesis of all of the nucleotides of the BRCA1 gene coding sequences, i.e., the exons. The set of primers preferably allows synthesis of both intron and exon sequences. Allele-specific primers can also be used. Such primers anneal only to particular BRCA1 mutant alleles, and thus will only amplify a product in the presence of the mutant allele as a template.

 In order to facilitate subsequent cloning of amplified sequences, primers may have restriction
25 enzyme site sequences appended to their 5' ends. Thus, all nucleotides of the primers are derived from BRCA1 sequences or sequences adjacent to BRCA1, except for the few nucleotides necessary to form a restriction enzyme site. Such enzymes and sites are well known in the art. The primers themselves can be synthesized using techniques which are well known in the art. Generally, the primers can be made using oligonucleotide synthesizing machines which are
30 commercially available. Given the sequence of the BRCA1 open reading frame shown in SEQ ID NO:1, design of particular primers is well within the skill of the art.

The nucleic acid probes provided by the present invention are useful for a number of purposes. They can be used in Southern hybridization to genomic DNA and in the RNase protection method for detecting point mutations already discussed above. The probes can be used to detect PCR amplification products. They may also be used to detect mismatches with the BRCA1 gene or mRNA using other techniques.

It has been discovered that individuals with the wild-type BRCA1 gene do not have cancer which results from the BRCA1 allele. However, mutations which interfere with the function of the BRCA1 protein are involved in the pathogenesis of cancer. Thus, the presence of an altered (or a mutant) BRCA1 gene which produces a protein having a loss of function, or altered function, directly correlates to an increased risk of cancer. In order to detect a BRCA1 gene mutation, a biological sample is prepared and analyzed for a difference between the sequence of the BRCA1 allele being analyzed and the sequence of the wild-type BRCA1 allele. Mutant BRCA1 alleles can be initially identified by any of the techniques described above. The mutant alleles are then sequenced to identify the specific mutation of the particular mutant allele. Alternatively, mutant BRCA1 alleles can be initially identified by identifying mutant (altered) BRCA1 proteins, using conventional techniques. The mutant alleles are then sequenced to identify the specific mutation for each allele. The mutations, especially those which lead to an altered function of the BRCA1 protein, are then used for the diagnostic and prognostic methods of the present invention.

Definitions

The present invention employs the following definitions:

"Amplification of Polynucleotides" utilizes methods such as the polymerase chain reaction (PCR), ligation amplification (or ligase chain reaction, LCR) and amplification methods based on the use of Q-beta replicase. These methods are well known and widely practiced in the art. See, e.g., U.S. Patents 4,683,195 and 4,683,202 and Innis *et al.*, 1990 (for PCR); and Wu *et al.*, 1989a (for LCR). Reagents and hardware for conducting PCR are commercially available. Primers useful to amplify sequences from the BRCA1 region are preferably complementary to, and hybridize specifically to sequences in the BRCA1 region or in regions that flank a target region therein. BRCA1 sequences generated by amplification may be sequenced directly. Alternatively, but less desirably, the amplified sequence(s) may be cloned prior to sequence analysis. A method for the direct cloning and sequence analysis of enzymatically amplified genomic segments has been described by Scharf, 1986.

"Analyte polynucleotide" and "analyte strand" refer to a single- or double-stranded polynucleotide which is suspected of containing a target sequence, and which may be present in a variety of types of samples, including biological samples.

"Antibodies." The present invention also provides polyclonal and/or monoclonal antibodies and fragments thereof, and immunologic binding equivalents thereof, which are capable of specifically binding to the BRCA1 polypeptides and fragments thereof or to polynucleotide sequences from the BRCA1 region, particularly from the BRCA1 locus or a portion thereof. The term "antibody" is used both to refer to a homogeneous molecular entity, or a mixture such as a serum product made up of a plurality of different molecular entities. Polypeptides may be prepared synthetically in a peptide synthesizer and coupled to a carrier molecule (e.g., keyhole limpet hemocyanin) and injected over several months into rabbits. Rabbit sera is tested for immunoreactivity to the BRCA1 polypeptide or fragment. Monoclonal antibodies may be made by injecting mice with the protein polypeptides, fusion proteins or fragments thereof. Monoclonal antibodies will be screened by ELISA and tested for specific immunoreactivity with BRCA1 polypeptide or fragments thereof. See, Harlow & Lane, 1988. These antibodies will be useful in assays as well as pharmaceuticals.

Once a sufficient quantity of desired polypeptide has been obtained, it may be used for various purposes. A typical use is the production of antibodies specific for binding. These antibodies may be either polyclonal or monoclonal, and may be produced by *in vitro* or *in vivo* techniques well known in the art. For production of polyclonal antibodies, an appropriate target immune system, typically mouse or rabbit, is selected. Substantially purified antigen is presented to the immune system in a fashion determined by methods appropriate for the animal and by other parameters well known to immunologists. Typical sites for injection are in footpads, intramuscularly, intraperitoneally, or intradermally. Of course, other species may be substituted for mouse or rabbit. Polyclonal antibodies are then purified using techniques known in the art, adjusted for the desired specificity.

An immunological response is usually assayed with an immunoassay. Normally, such immunoassays involve some purification of a source of antigen, for example, that produced by the same cells and in the same fashion as the antigen. A variety of immunoassay methods are well known in the art. See, e.g., Harlow & Lane, 1988, or Goding, 1986.

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Monoclonal antibodies with affinities of 10^{-8} M^{-1} or preferably 10^{-9} to 10^{-10} M^{-1} or stronger will typically be made by standard procedures as described, e.g., in Harlow & Lane, 1988 or Goding, 1986. Briefly, appropriate animals will be selected and the desired immunization protocol followed. After the appropriate period of time, the spleens of such animals are excised and individual spleen cells fused, typically, to immortalized myeloma cells under appropriate selection conditions. Thereafter, the cells are clonally separated and the supernatants of each clone tested for their production of an appropriate antibody specific for the desired region of the antigen.

Other suitable techniques involve *in vitro* exposure of lymphocytes to the antigenic polypeptides, or alternatively, to selection of libraries of antibodies in phage or similar vectors. See Huse *et al.*, 1989. The polypeptides and antibodies of the present invention may be used with or without modification. Frequently, polypeptides and antibodies will be labeled by joining, either covalently or non-covalently, a substance which provides for a detectable signal. A wide variety of labels and conjugation techniques are known and are reported extensively in both the scientific and patent literature. Suitable labels include radionuclides, enzymes, substrates, cofactors, inhibitors, fluorescent agents, chemiluminescent agents, magnetic particles and the like. Patents teaching the use of such labels include U.S. Patents 3,817,837; 3,850,752; 3,939,350; 3,996,345; 4,277,437; 4,275,149 and 4,366,241. Also, recombinant immunoglobulins may be produced (see U.S. Patent 4,816,567).

"**Binding partner**" refers to a molecule capable of binding a ligand molecule with high specificity, as for example, an antigen and an antigen-specific antibody or an enzyme and its inhibitor. In general, the specific binding partners must bind with sufficient affinity to immobilize the analyte copy/complementary strand duplex (in the case of polynucleotide hybridization) under the isolation conditions. Specific binding partners are known in the art and include, for example, biotin and avidin or streptavidin, IgG and protein A, the numerous, known receptor-ligand couples, and complementary polynucleotide strands. In the case of complementary polynucleotide binding partners, the partners are normally at least about 15 bases in length, and may be at least 40 bases in length. The polynucleotides may be composed of DNA, RNA, or synthetic nucleotide analogs.

A "**biological sample**" refers to a sample of tissue or fluid suspected of containing an analyte polynucleotide or polypeptide from an individual including, but not limited to, e.g., plasma, serum, spinal fluid, lymph fluid, the external sections of the skin, respiratory, intestinal, and genito-

urinary tracts, tears, saliva, blood cells, tumors, organs, tissue and samples of *in vitro* cell culture constituents.

As used herein, the terms "**diagnosing**" or "**prognosing**," as used in the context of neoplasia, are used to indicate 1) the classification of lesions as neoplasia, 2) the determination of the severity of the neoplasia, or 3) the monitoring of the disease progression, prior to, during and after treatment.

"**Encode**". A polynucleotide is said to "encode" a polypeptide if, in its native state or when manipulated by methods well known to those skilled in the art, it can be transcribed and/or translated to produce the mRNA for and/or the polypeptide or a fragment thereof. The anti-sense strand is the complement of such a nucleic acid, and the encoding sequence can be deduced therefrom.

"**Isolated**" or "**substantially pure**". An "isolated" or "substantially pure" nucleic acid (e.g., an RNA, DNA or a mixed polymer) is one which is substantially separated from other cellular components which naturally accompany a native human sequence or protein, e.g., ribosomes, polymerases, many other human genome sequences and proteins. The term embraces a nucleic acid sequence or protein which has been removed from its naturally occurring environment, and includes recombinant or cloned DNA isolates and chemically synthesized analogs or analogs biologically synthesized by heterologous systems.

"**BRCA1 Allele**" refers to normal alleles of the BRCA1 locus as well as alleles carrying variations that predispose individuals to develop cancer of many sites including, for example, breast, ovarian, colorectal and prostate cancer. Such predisposing alleles are also called "**BRCA1 susceptibility alleles**".

"**BRCA1 Locus**," "**BRCA1 Gene**," "**BRCA1 Nucleic Acids**" or "**BRCA1 Polynucleotide**" each refer to polynucleotides, all of which are in the BRCA1 region, that are likely to be expressed in normal tissue, certain alleles of which predispose an individual to develop breast, ovarian, colorectal and prostate cancers. Mutations at the BRCA1 locus may be involved in the initiation and/or progression of other types of tumors. The locus is indicated in part by mutations that predispose individuals to develop cancer. These mutations fall within the BRCA1 region described *infra*. The BRCA1 locus is intended to include coding sequences, intervening sequences and regulatory elements controlling transcription and/or translation. The BRCA1 locus is intended to include all allelic variations of the DNA sequence.

These terms, when applied to a nucleic acid, refer to a nucleic acid which encodes a BRCA1 polypeptide, fragment, homolog or variant, including, e.g., protein fusions or deletions. The nucleic acids of the present invention will possess a sequence which is either derived from, or substantially similar to a natural BRCA1-encoding gene or one having substantial homology with a natural BRCA1-encoding gene or a portion thereof. The coding sequence for a BRCA1 polypeptide is shown in SEQ ID NO:1, with the amino acid sequence shown in SEQ ID NO:2.

The polynucleotide compositions of this invention include RNA, cDNA, genomic DNA, synthetic forms, and mixed polymers, both sense and antisense strands, and may be chemically or biochemically modified or may contain non-natural or derivatized nucleotide bases, as will be readily appreciated by those skilled in the art. Such modifications include, for example, labels, methylation, substitution of one or more of the naturally occurring nucleotides with an analog, internucleotide modifications such as uncharged linkages (e.g., methyl phosphonates, phosphotriesters, phosphoramidates, carbamates, etc.), charged linkages (e.g., phosphorothioates, phosphorodithioates, etc.), pendent moieties (e.g., polypeptides), intercalators (e.g., acridine, psoralen, etc.), chelators, alkylators, and modified linkages (e.g., alpha anomeric nucleic acids, etc.). Also included are synthetic molecules that mimic polynucleotides in their ability to bind to a designated sequence via hydrogen bonding and other chemical interactions. Such molecules are known in the art and include, for example, those in which peptide linkages substitute for phosphate linkages in the backbone of the molecule.

The present invention provides recombinant nucleic acids comprising all or part of the BRCA1 region. The recombinant construct may be capable of replicating autonomously in a host cell. Alternatively, the recombinant construct may become integrated into the chromosomal DNA of the host cell. Such a recombinant polynucleotide comprises a polynucleotide of genomic, cDNA, semi-synthetic, or synthetic origin which, by virtue of its origin or manipulation, 1) is not associated with all or a portion of a polynucleotide with which it is associated in nature; 2) is linked to a polynucleotide other than that to which it is linked in nature; or 3) does not occur in nature.

Therefore, recombinant nucleic acids comprising sequences otherwise not naturally occurring are provided by this invention. Although the wild-type sequence may be employed, it will often be altered, e.g., by deletion, substitution or insertion.

cDNA or genomic libraries of various types may be screened as natural sources of the nucleic acids of the present invention, or such nucleic acids may be provided by amplification of

sequences resident in genomic DNA or other natural sources, e.g., by PCR. The choice of cDNA libraries normally corresponds to a tissue source which is abundant in mRNA for the desired proteins. Phage libraries are normally preferred, but other types of libraries may be used. Clones of a library are spread onto plates, transferred to a substrate for screening, denatured and probed for the presence of desired sequences.

The DNA sequences used in this invention will usually comprise at least about five codons (15 nucleotides), more usually at least about 7-15 codons, and most preferably, at least about 35 codons. One or more introns may also be present. This number of nucleotides is usually about the minimal length required for a successful probe that would hybridize specifically with a BRCA1-encoding sequence.

Techniques for nucleic acid manipulation are described generally, for example, in Sambrook *et al.*, 1989 or Ausubel *et al.*, 1992. Reagents useful in applying such techniques, such as restriction enzymes and the like, are widely known in the art and commercially available from such vendors as New England BioLabs, Boehringer Mannheim, Amersham, Promega Biotec, U. S. Biochemicals, New England Nuclear, and a number of other sources. The recombinant nucleic acid sequences used to produce fusion proteins of the present invention may be derived from natural or synthetic sequences. Many natural gene sequences are obtainable from various cDNA or from genomic libraries using appropriate probes. See, GenBank, National Institutes of Health.

"BRCA1 Region" refers to a portion of human chromosome 17q21 bounded by the markers tdj1474 and U5R. This region contains the BRCA1 locus, including the BRCA1 gene.

As used herein, the terms "BRCA1 locus," "BRCA1 allele" and "BRCA1 region" all refer to the double-stranded DNA comprising the locus, allele, or region, as well as either of the single-stranded DNAs comprising the locus, allele or region.

As used herein, a "portion" of the BRCA1 locus or region or allele is defined as having a minimal size of at least about eight nucleotides, or preferably about 15 nucleotides, or more preferably at least about 25 nucleotides, and may have a minimal size of at least about 40 nucleotides.

"BRCA1 protein" or "BRCA1 polypeptide" refer to a protein or polypeptide encoded by the BRCA1 locus, variants or fragments thereof. The term "polypeptide" refers to a polymer of amino acids and its equivalent and does not refer to a specific length of the product; thus, peptides, oligopeptides and proteins are included within the definition of a polypeptide. This term also does

not refer to, or exclude modifications of the polypeptide, for example, glycosylations, acetylations, phosphorylations, and the like. Included within the definition are, for example, polypeptides containing one or more analogs of an amino acid (including, for example, unnatural amino acids, etc.), polypeptides with substituted linkages as well as other modifications known in the art, both
5 naturally and non-naturally occurring. Ordinarily, such polypeptides will be at least about 50% homologous to the native BRCA1 sequence, preferably in excess of about 90%, and more preferably at least about 95% homologous. Also included are proteins encoded by DNA which hybridize under high or low stringency conditions, to BRCA1-encoding nucleic acids and closely related polypeptides or proteins retrieved by antisera to the BRCA1 protein(s).

10 The length of polypeptide sequences compared for homology will generally be at least about 16 amino acids, usually at least about 20 residues, more usually at least about 24 residues, typically at least about 28 residues, and preferably more than about 35 residues.

"Operably linked" refers to a juxtaposition wherein the components so described are in a relationship permitting them to function in their intended manner. For instance, a promoter is
15 operably linked to a coding sequence if the promoter affects its transcription or expression.

"Probes". Polynucleotide polymorphisms associated with BRCA1 alleles which predispose to certain cancers or are associated with most cancers are detected by hybridization with a polynucleotide probe which forms a stable hybrid with that of the target sequence, under stringent to moderately stringent hybridization and wash conditions. If it is expected that the probes will be
20 perfectly complementary to the target sequence, stringent conditions will be used. Hybridization stringency may be lessened if some mismatching is expected, for example, if variants are expected with the result that the probe will not be completely complementary. Conditions are chosen which rule out nonspecific/adventitious bindings, that is, which minimize noise. Since such indications identify neutral DNA polymorphisms as well as mutations, these indications need further analysis
25 to demonstrate detection of a BRCA1 susceptibility allele.

Probes for BRCA1 alleles may be derived from the sequences of the BRCA1 region or its cDNAs. The probes may be of any suitable length, which span all or a portion of the BRCA1 region, and which allow specific hybridization to the BRCA1 region. If the target sequence contains a sequence identical to that of the probe, the probes may be short, e.g., in the range of
30 about 8-30 base pairs, since the hybrid will be relatively stable under even stringent conditions. If some degree of mismatch is expected with the probe, i.e., if it is suspected that the probe will

hybridize to a variant region, a longer probe may be employed which hybridizes to the target sequence with the requisite specificity.

The probes will include an isolated polynucleotide attached to a label or reporter molecule and may be used to isolate other polynucleotide sequences, having sequence similarity by standard methods. For techniques for preparing and labeling probes see, e.g., Sambrook *et al.*, 1989 or Ausubel *et al.*, 1992. Other similar polynucleotides may be selected by using homologous polynucleotides. Alternatively, polynucleotides encoding these or similar polypeptides may be synthesized or selected by use of the redundancy in the genetic code. Various codon substitutions may be introduced, e.g., by silent changes (thereby producing various restriction sites) or to optimize expression for a particular system. Mutations may be introduced to modify the properties of the polypeptide, perhaps to change ligand-binding affinities, interchain affinities, or the polypeptide degradation or turnover rate.

Probes comprising synthetic oligonucleotides or other polynucleotides of the present invention may be derived from naturally occurring or recombinant single- or double-stranded polynucleotides, or be chemically synthesized. Probes may also be labeled by nick translation, Klenow fill-in reaction, or other methods known in the art.

Portions of the polynucleotide sequence having at least about eight nucleotides, usually at least about 15 nucleotides, and fewer than about 6 kb, usually fewer than about 1.0 kb, from a polynucleotide sequence encoding BRCA1 are preferred as probes. The probes may also be used to determine whether mRNA encoding BRCA1 is present in a cell or tissue.

"Protein modifications or fragments" are provided by the present invention for BRCA1 polypeptides or fragments thereof which are substantially homologous to primary structural sequence but which include, e.g., *in vivo* or *in vitro* chemical and biochemical modifications or which incorporate unusual amino acids. Such modifications include, for example, acetylation, carboxylation, phosphorylation, glycosylation, ubiquitination, labeling, e.g., with radionuclides, and various enzymatic modifications, as will be readily appreciated by those well skilled in the art.

A variety of methods for labeling polypeptides and of substituents or labels useful for such purposes are well known in the art, and include radioactive isotopes such as ^{32}P , ligands which bind to labeled antiligands (e.g., antibodies), fluorophores, chemiluminescent agents, enzymes, and antiligands which can serve as specific binding pair members for a labeled ligand. The choice of label depends on the sensitivity required, ease of conjugation with the primer, stability

requirements, and available instrumentation. Methods of labeling polypeptides are well known in the art. See, e.g., Sambrook *et al.*, 1989 or Ausubel *et al.*, 1992.

Besides substantially full-length polypeptides, the present invention provides for biologically active fragments of the polypeptides. Significant biological activities include ligand-binding, immunological activity and other biological activities characteristic of BRCA1 polypeptides. Immunological activities include both immunogenic function in a target immune system, as well as sharing of immunological epitopes for binding, serving as either a competitor or substitute antigen for an epitope of the BRCA1 protein. As used herein, "epitope" refers to an antigenic determinant of a polypeptide. An epitope could comprise three amino acids in a spatial conformation which is unique to the epitope. Generally, an epitope consists of at least five such amino acids, and more usually consists of at least 8-10 such amino acids. Methods of determining the spatial conformation of such amino acids are known in the art.

For immunological purposes, tandem-repeat polypeptide segments may be used as immunogens, thereby producing highly antigenic proteins. Alternatively, such polypeptides will serve as highly efficient competitors for specific binding. Production of antibodies specific for BRCA1 polypeptides or fragments thereof is described below.

The present invention also provides for fusion polypeptides, comprising BRCA1 polypeptides and fragments. Homologous polypeptides may be fusions between two or more BRCA1 polypeptide sequences or between the sequences of BRCA1 and a related protein. Likewise, heterologous fusions may be constructed which would exhibit a combination of properties or activities of the derivative proteins. For example, ligand-binding or other domains may be "swapped" between different new fusion polypeptides or fragments. Such homologous or heterologous fusion polypeptides may display, for example, altered strength or specificity of binding. Fusion partners include immunoglobulins, bacterial β -galactosidase, trpE, protein A, β -lactamase, alpha amylase, alcohol dehydrogenase and yeast alpha mating factor. See, e.g., Godowski *et al.*, 1988.

Fusion proteins will typically be made by either recombinant nucleic acid methods, as described below, or may be chemically synthesized. Techniques for the synthesis of polypeptides are described, for example, in Merrifield, 1963.

"Protein purification" refers to various methods for the isolation of the BRCA1 polypeptides from other biological material, such as from cells transformed with recombinant

nucleic acids encoding BRCA1, and are well known in the art. For example, such polypeptides may be purified by immunoaffinity chromatography employing, e.g., the antibodies provided by the present invention. Various methods of protein purification are well known in the art, and include those described in Deutscher, 1990 and Scopes, 1982.

5 The terms **"isolated"**, **"substantially pure"**, and **"substantially homogeneous"** are used interchangeably to describe a protein or polypeptide which has been separated from components which accompany it in its natural state. A monomeric protein is substantially pure when at least about 60 to 75% of a sample exhibits a single polypeptide sequence. A substantially pure protein will typically comprise about 60 to 90% W/W of a protein sample, more usually about 95%, and
10 preferably will be over about 99% pure. Protein purity or homogeneity may be indicated by a number of means well known in the art, such as polyacrylamide gel electrophoresis of a protein sample, followed by visualizing a single polypeptide band upon staining the gel. For certain purposes, higher resolution may be provided by using HPLC or other means well known in the art which are utilized for purification.

15 A BRCA1 protein is substantially free of naturally associated components when it is separated from the native contaminants which accompany it in its natural state. Thus, a polypeptide which is chemically synthesized or synthesized in a cellular system different from the cell from which it naturally originates will be substantially free from its naturally associated components. A protein may also be rendered substantially free of naturally associated components by isolation,
20 using protein purification techniques well known in the art.

A polypeptide produced as an expression product of an isolated and manipulated genetic sequence is an **"isolated polypeptide,"** as used herein, even if expressed in a homologous cell type. Synthetically made forms or molecules expressed by heterologous cells are inherently isolated molecules.

25 **"Recombinant nucleic acid"** is a nucleic acid which is not naturally occurring, or which is made by the artificial combination of two otherwise separated segments of sequence. This artificial combination is often accomplished by either chemical synthesis means, or by the artificial manipulation of isolated segments of nucleic acids, e.g., by genetic engineering techniques. Such is usually done to replace a codon with a redundant codon encoding the same or a conservative
30 amino acid, while typically introducing or removing a sequence recognition site. Alternatively, it

is performed to join together nucleic acid segments of desired functions to generate a desired combination of functions.

"Regulatory sequences" refers to those sequences normally within 100 kb of the coding region of a locus, but they may also be more distant from the coding region, which affect the expression of the gene (including transcription of the gene, and translation, splicing, stability or the like of the messenger RNA).

"Substantial homology or similarity". A nucleic acid or fragment thereof is "substantially homologous" ("or substantially similar") to another if, when optimally aligned (with appropriate nucleotide insertions or deletions) with the other nucleic acid (or its complementary strand), there is nucleotide sequence identity in at least about 60% of the nucleotide bases, usually at least about 70%, more usually at least about 80%, preferably at least about 90%, and more preferably at least about 95-98% of the nucleotide bases.

Alternatively, substantial homology or (similarity) exists when a nucleic acid or fragment thereof will hybridize to another nucleic acid (or a complementary strand thereof) under selective hybridization conditions, to a strand, or to its complement. Selectivity of hybridization exists when hybridization which is substantially more selective than total lack of specificity occurs. Typically, selective hybridization will occur when there is at least about 55% homology over a stretch of at least about 14 nucleotides, preferably at least about 65%, more preferably at least about 75%, and most preferably at least about 90%. See, Kanehisa, 1984. The length of homology comparison, as described, may be over longer stretches, and in certain embodiments will often be over a stretch of at least about nine nucleotides, usually at least about 20 nucleotides, more usually at least about 24 nucleotides, typically at least about 28 nucleotides, more typically at least about 32 nucleotides, and preferably at least about 36 or more nucleotides.

Nucleic acid hybridization will be affected by such conditions as salt concentration, temperature, or organic solvents, in addition to the base composition, length of the complementary strands, and the number of nucleotide base mismatches between the hybridizing nucleic acids, as will be readily appreciated by those skilled in the art. Stringent temperature conditions will generally include temperatures in excess of 30°C, typically in excess of 37°C, and preferably in excess of 45°C. Stringent salt conditions will ordinarily be less than 1000 mM, typically less than 500 mM, and preferably less than 200 mM. However, the combination of parameters is much more important than the measure of any single parameter. See, e.g., Wetmur & Davidson, 1968.

Probe sequences may also hybridize specifically to duplex DNA under certain conditions to form triplex or other higher order DNA complexes. The preparation of such probes and suitable hybridization conditions are well known in the art.

The terms "**substantial homology**" or "**substantial identity**", when referring to
5 polypeptides, indicate that the polypeptide or protein in question exhibits at least about 30% identity with an entire naturally-occurring protein or a portion thereof, usually at least about 70% identity, and preferably at least about 95% identity.

"**Substantially similar function**" refers to the function of a modified nucleic acid or a modified protein, with reference to the wild-type BRCA1 nucleic acid or wild-type BRCA1
10 polypeptide. The modified polypeptide will be substantially homologous to the wild-type BRCA1 polypeptide and will have substantially the same function. The modified polypeptide may have an altered amino acid sequence and/or may contain modified amino acids. In addition to the similarity of function, the modified polypeptide may have other useful properties, such as a longer half-life. The similarity of function (activity) of the modified polypeptide may be substantially the
15 same as the activity of the wild-type BRCA1 polypeptide. Alternatively, the similarity of function (activity) of the modified polypeptide may be higher than the activity of the wild-type BRCA1 polypeptide. The modified polypeptide is synthesized using conventional techniques, or is encoded by a modified nucleic acid and produced using conventional techniques. The modified nucleic acid is prepared by conventional techniques. A nucleic acid with a function substantially
20 similar to the wild-type BRCA1 gene function produces the modified protein described above.

Homology, for polypeptides, is typically measured using sequence analysis software. See, e.g., the Sequence Analysis Software Package of the Genetics Computer Group, University of Wisconsin Biotechnology Center, 910 University Avenue, Madison, Wisconsin 53705. Protein analysis software matches similar sequences using measure of homology assigned to various
25 substitutions, deletions and other modifications. Conservative substitutions typically include substitutions within the following groups: glycine, alanine; valine, isoleucine, leucine; aspartic acid, glutamic acid; asparagine, glutamine; serine, threonine; lysine, arginine; and phenylalanine, tyrosine.

A polypeptide "**fragment**," "**portion**" or "**segment**" is a stretch of amino acid residues of at
30 least about five to seven contiguous amino acids, often at least about seven to nine contiguous

amino acids, typically at least about nine to 13 contiguous amino acids and, most preferably, at least about 20 to 30 or more contiguous amino acids.

The polypeptides of the present invention, if soluble, may be coupled to a solid-phase support, e.g., nitrocellulose, nylon, column packing materials (e.g., Sepharose beads), magnetic
5 beads, glass wool, plastic, metal, polymer gels, cells, or other substrates. Such supports may take the form, for example, of beads, wells, dipsticks, or membranes.

"Target region" refers to a region of the nucleic acid which is amplified and/or detected. The term "target sequence" refers to a sequence with which a probe or primer will form a stable hybrid under desired conditions.

10 The practice of the present invention employs, unless otherwise indicated, conventional techniques of chemistry, molecular biology, microbiology, recombinant DNA, genetics, and immunology. See, e.g., Maniatis *et al.*, 1982; Sambrook *et al.*, 1989; Ausubel *et al.*, 1992; Glover, 1985; Anand, 1992; Guthrie & Fink, 1991. A general discussion of techniques and materials for human gene mapping, including mapping of human chromosome 17q, is provided, e.g., in White
15 and Lalouel, 1988.

Preparation of recombinant or chemically synthesized
nucleic acids; vectors, transformation, host cells

Large amounts of the polynucleotides of the present invention may be produced by
20 replication in a suitable host cell. Natural or synthetic polynucleotide fragments coding for a desired fragment will be incorporated into recombinant polynucleotide constructs, usually DNA constructs, capable of introduction into and replication in a prokaryotic or eukaryotic cell. Usually the polynucleotide constructs will be suitable for replication in a unicellular host, such as yeast or bacteria, but may also be intended for introduction to (with and without integration within the
25 genome) cultured mammalian or plant or other eukaryotic cell lines. The purification of nucleic acids produced by the methods of the present invention is described, e.g., in Sambrook *et al.*, 1989 or Ausubel *et al.*, 1992.

The polynucleotides of the present invention may also be produced by chemical synthesis, e.g., by the phosphoramidite method described by Beaucage & Carruthers, 1981 or the triester
30 method according to Matteucci and Caruthers, 1981, and may be performed on commercial, automated oligonucleotide synthesizers. A double-stranded fragment may be obtained from the

single-stranded product of chemical synthesis either by synthesizing the complementary strand and annealing the strands together under appropriate conditions or by adding the complementary strand using DNA polymerase with an appropriate primer sequence.

Polynucleotide constructs prepared for introduction into a prokaryotic or eukaryotic host may comprise a replication system recognized by the host, including the intended polynucleotide fragment encoding the desired polypeptide, and will preferably also include transcription and translational initiation regulatory sequences operably linked to the polypeptide encoding segment. Expression vectors may include, for example, an origin of replication or autonomously replicating sequence (ARS) and expression control sequences, a promoter, an enhancer and necessary processing information sites, such as ribosome-binding sites, RNA splice sites, polyadenylation sites, transcriptional terminator sequences, and mRNA stabilizing sequences. Secretion signals may also be included where appropriate, whether from a native BRCA1 protein or from other receptors or from secreted polypeptides of the same or related species, which allow the protein to cross and/or lodge in cell membranes, and thus attain its functional topology, or be secreted from the cell. Such vectors may be prepared by means of standard recombinant techniques well known in the art and discussed, for example, in Sambrook *et al.*, 1989 or Ausubel *et al.* 1992.

An appropriate promoter and other necessary vector sequences will be selected so as to be functional in the host, and may include, when appropriate, those naturally associated with BRCA1 genes. Examples of workable combinations of cell lines and expression vectors are described in Sambrook *et al.*, 1989 or Ausubel *et al.*, 1992; see also, e.g., Metzger *et al.*, 1988. Many useful vectors are known in the art and may be obtained from such vendors as Stratagene, New England Biolabs, Promega Biotech, and others. Promoters such as the *trp*, *lac* and phage promoters, tRNA promoters and glycolytic enzyme promoters may be used in prokaryotic hosts. Useful yeast promoters include promoter regions for metallothionein, 3-phosphoglycerate kinase or other glycolytic enzymes such as enolase or glyceraldehyde-3-phosphate dehydrogenase, enzymes responsible for maltose and galactose utilization, and others. Vectors and promoters suitable for use in yeast expression are further described in Hitzeman *et al.*, EP 73,675A. Appropriate non-native mammalian promoters might include the early and late promoters from SV40 (Fiers *et al.*, 1978) or promoters derived from murine Moloney leukemia virus, mouse tumor virus, avian sarcoma viruses, adenovirus II, bovine papilloma virus or polyoma. In addition, the construct may be joined to an amplifiable gene (e.g., DHFR) so that multiple copies of the gene may be made. For

appropriate enhancer and other expression control sequences, see also *Enhancers and Eukaryotic Gene Expression*, Cold Spring Harbor Press, Cold Spring Harbor, New York (1983).

While such expression vectors may replicate autonomously, they may also replicate by being inserted into the genome of the host cell, by methods well known in the art.

5 Expression and cloning vectors will likely contain a selectable marker, a gene encoding a protein necessary for survival or growth of a host cell transformed with the vector. The presence of this gene ensures growth of only those host cells which express the inserts. Typical selection genes encode proteins that a) confer resistance to antibiotics or other toxic substances, e.g. ampicillin, neomycin, methotrexate, etc.; b) complement auxotrophic deficiencies, or c) supply critical
10 nutrients not available from complex media, e.g., the gene encoding D-alanine racemase for *Bacilli*. The choice of the proper selectable marker will depend on the host cell, and appropriate markers for different hosts are well known in the art.

The vectors containing the nucleic acids of interest can be transcribed *in vitro*, and the resulting RNA introduced into the host cell by well-known methods, e.g., by injection (see, Kubo
15 *et al.*, 1988), or the vectors can be introduced directly into host cells by methods well known in the art, which vary depending on the type of cellular host, including electroporation; transfection employing calcium chloride, rubidium chloride, calcium phosphate, DEAE-dextran, or other substances; microprojectile bombardment; lipofection; infection (where the vector is an infectious agent, such as a retroviral genome); and other methods. See generally, Sambrook *et al.*, 1989 and
20 Ausubel *et al.*, 1992. The introduction of the polynucleotides into the host cell by any method known in the art, including, *inter alia*, those described above, will be referred to herein as "transformation." The cells into which have been introduced nucleic acids described above are meant to also include the progeny of such cells.

Large quantities of the nucleic acids and polypeptides of the present invention may be
25 prepared by expressing the BRCA1 nucleic acids or portions thereof in vectors or other expression vehicles in compatible prokaryotic or eukaryotic host cells. The most commonly used prokaryotic hosts are strains of *Escherichia coli*, although other prokaryotes, such as *Bacillus subtilis* or *Pseudomonas* may also be used.

Mammalian or other eukaryotic host cells, such as those of yeast, filamentous fungi, plant,
30 insect, or amphibian or avian species, may also be useful for production of the proteins of the present invention. Propagation of mammalian cells in culture is *per se* well known. See, Jakoby

and Pastan, 1979. Examples of commonly used mammalian host cell lines are VERO and HeLa cells, Chinese hamster ovary (CHO) cells, and WI38, BHK, and COS cell lines, although it will be appreciated by the skilled practitioner that other cell lines may be appropriate, e.g., to provide higher expression, desirable glycosylation patterns, or other features.

5 Clones are selected by using markers depending on the mode of the vector construction. The marker may be on the same or a different DNA molecule, preferably the same DNA molecule. In prokaryotic hosts, the transformant may be selected, e.g., by resistance to ampicillin, tetracycline or other antibiotics. Production of a particular product based on temperature sensitivity may also serve as an appropriate marker.

10 Prokaryotic or eukaryotic cells transformed with the polynucleotides of the present invention will be useful not only for the production of the nucleic acids and polypeptides of the present invention, but also, for example, in studying the characteristics of BRCA1 polypeptides.

Antisense polynucleotide sequences are useful in preventing or diminishing the expression of the BRCA1 locus, as will be appreciated by those skilled in the art. For example, polynucleotide
15 vectors containing all or a portion of the BRCA1 locus or other sequences from the BRCA1 region (particularly those flanking the BRCA1 locus) may be placed under the control of a promoter in an antisense orientation and introduced into a cell. Expression of such an antisense construct within a cell will interfere with BRCA1 transcription and/or translation and/or replication.

The probes and primers based on the BRCA1 gene sequences disclosed herein are used to
20 identify homologous BRCA1 gene sequences and proteins in other species. These BRCA1 gene sequences and proteins are used in the diagnostic/prognostic, therapeutic and drug screening methods described herein for the species from which they have been isolated.

Methods of Use: Nucleic Acid Diagnosis and Diagnostic Kits

25 In order to detect the presence of a BRCA1 allele predisposing an individual to cancer, a biological sample such as blood is prepared and analyzed for the presence or absence of susceptibility alleles of BRCA1. In order to detect the presence of neoplasia, the progression toward malignancy of a precursor lesion, or as a prognostic indicator, a biological sample of the lesion is prepared and analyzed for the presence or absence of mutant alleles of BRCA1. Results of
30 these tests and interpretive information are returned to the health care provider for communication to the tested individual. Such diagnoses may be performed by diagnostic laboratories, or,

alternatively, diagnostic kits are manufactured and sold to health care providers or to private individuals for self-diagnosis.

Initially, the screening method involves amplification of the relevant BRCA1 sequences. In another preferred embodiment of the invention, the screening method involves a non-PCR based strategy. Such screening methods include two-step label amplification methodologies that are well known in the art. Both PCR and non-PCR based screening strategies can detect target sequences with a high level of sensitivity.

The most popular method used today is target amplification. Here, the target nucleic acid sequence is amplified with polymerases. One particularly preferred method using polymerase-driven amplification is the polymerase chain reaction (PCR). The polymerase chain reaction and other polymerase-driven amplification assays can achieve over a million-fold increase in copy number through the use of polymerase-driven amplification cycles. Once amplified, the resulting nucleic acid can be sequenced or used as a substrate for DNA probes.

When the probes are used to detect the presence of the target sequences (for example, in screening for cancer susceptibility), the biological sample to be analyzed, such as blood or serum, may be treated, if desired, to extract the nucleic acids. The sample nucleic acid may be prepared in various ways to facilitate detection of the target sequence; e.g. denaturation, restriction digestion, electrophoresis or dot blotting. The targeted region of the analyte nucleic acid usually must be at least partially single-stranded to form hybrids with the targeting sequence of the probe. If the sequence is naturally single-stranded, denaturation will not be required. However, if the sequence is double-stranded, the sequence will probably need to be denatured. Denaturation can be carried out by various techniques known in the art.

Analyte nucleic acid and probe are incubated under conditions which promote stable hybrid formation of the target sequence in the probe with the putative targeted sequence in the analyte.

The region of the probes which is used to bind to the analyte can be made completely complementary to the targeted region of human chromosome 17q. Therefore, high stringency conditions are desirable in order to prevent false positives. However, conditions of high stringency are used only if the probes are complementary to regions of the chromosome which are unique in the genome. The stringency of hybridization is determined by a number of factors during hybridization and during the washing procedure, including temperature, ionic strength, base composition, probe length, and concentration of formamide. These factors are outlined in, for

example, Maniatis *et al.*, 1982 and Sambrook *et al.*, 1989. Under certain circumstances, the formation of higher order hybrids, such as triplexes, quadraplexes, etc., may be desired to provide the means of detecting target sequences.

Detection, if any, of the resulting hybrid is usually accomplished by the use of labeled probes. Alternatively, the probe may be unlabeled, but may be detectable by specific binding with a ligand which is labeled, either directly or indirectly. Suitable labels, and methods for labeling probes and ligands are known in the art, and include, for example, radioactive labels which may be incorporated by known methods (e.g., nick translation, random priming or kinasing), biotin, fluorescent groups, chemiluminescent groups (e.g., dioxetanes, particularly triggered dioxetanes), enzymes, antibodies and the like. Variations of this basic scheme are known in the art, and include those variations that facilitate separation of the hybrids to be detected from extraneous materials and/or that amplify the signal from the labeled moiety. A number of these variations are reviewed in, e.g., Matthews & Kricka, 1988; Landegren *et al.*, 1988; Mittlin, 1989; U.S. Patent 4,868,105, and in EPO Publication No. 225,807.

As noted above, non-PCR based screening assays are also contemplated in this invention. An exemplary non-PCR based procedure is provided in Example 11. This procedure hybridizes a nucleic acid probe (or an analog such as a methyl phosphonate backbone replacing the normal phosphodiester), to the low level DNA target. This probe may have an enzyme covalently linked to the probe, such that the covalent linkage does not interfere with the specificity of the hybridization. This enzyme-probe-conjugate-target nucleic acid complex can then be isolated away from the free probe enzyme conjugate and a substrate is added for enzyme detection. Enzymatic activity is observed as a change in color development or luminescent output resulting in a 10^3 - 10^6 increase in sensitivity. For an example relating to the preparation of oligodeoxynucleotide-alkaline phosphatase conjugates and their use as hybridization probes see Jablonski *et al.*, 1986.

Two-step label amplification methodologies are known in the art. These assays work on the principle that a small ligand (such as digoxigenin, biotin, or the like) is attached to a nucleic acid probe capable of specifically binding BRCA1. Exemplary probes are provided in Table 9 of this patent application and additionally include the nucleic acid probe corresponding to nucleotide positions 3631 to 3930 of SEQ ID NO:1. Allele specific probes are also contemplated within the

scope of this example and exemplary allele specific probes include probes encompassing the predisposing mutations summarized in Tables 11 and 12 of this patent application.

In one example, the small ligand attached to the nucleic acid probe is specifically recognized by an antibody-enzyme conjugate. In one embodiment of this example, digoxigenin is attached to the nucleic acid probe. Hybridization is detected by an antibody-alkaline phosphatase conjugate which turns over a chemiluminescent substrate. For methods for labeling nucleic acid probes according to this embodiment see Martin *et al.*, 1990. In a second example, the small ligand is recognized by a second ligand-enzyme conjugate that is capable of specifically complexing to the first ligand. A well known embodiment of this example is the biotin-avidin type of interactions.

For methods for labeling nucleic acid probes and their use in biotin-avidin based assays see Rigby *et al.*, 1977 and Nguyen *et al.*, 1992.

It is also contemplated within the scope of this invention that the nucleic acid probe assays of this invention will employ a cocktail of nucleic acid probes capable of detecting BRCA1. Thus, in one example to detect the presence of BRCA1 in a cell sample, more than one probe complementary to BRCA1 is employed and in particular the number of different probes is alternatively 2, 3, or 5 different nucleic acid probe sequences. In another example, to detect the presence of mutations in the BRCA1 gene sequence in a patient, more than one probe complementary to BRCA1 is employed where the cocktail includes probes capable of binding to the allele-specific mutations identified in populations of patients with alterations in BRCA1. In this embodiment, any number of probes can be used, and will preferably include probes corresponding to the major gene mutations identified as predisposing an individual to breast cancer. Some candidate probes contemplated within the scope of the invention include probes that include the allele-specific mutations identified in Tables 11 and 12 and those that have the BRCA1 regions corresponding to SEQ ID NO:1 both 5' and 3' to the mutation site.

Methods of Use: Peptide Diagnosis and Diagnostic Kits

The neoplastic condition of lesions can also be detected on the basis of the alteration of wild-type BRCA1 polypeptide. Such alterations can be determined by sequence analysis in accordance with conventional techniques. More preferably, antibodies (polyclonal or monoclonal) are used to detect differences in, or the absence of BRCA1 peptides. The antibodies may be prepared as discussed above under the heading "Antibodies" and as further shown in Examples 12 and 13.

Other techniques for raising and purifying antibodies are well known in the art and any such techniques may be chosen to achieve the preparations claimed in this invention. In a preferred embodiment of the invention, antibodies will immunoprecipitate BRCA1 proteins from solution as well as react with BRCA1 protein on Western or immunoblots of polyacrylamide gels. In another preferred embodiment, antibodies will detect BRCA1 proteins in paraffin or frozen tissue sections, using immunocytochemical techniques.

Preferred embodiments relating to methods for detecting BRCA1 or its mutations include enzyme linked immunosorbent assays (ELISA), radioimmunoassays (RIA), immunoradiometric assays (IRMA) and immunoenzymatic assays (IEMA), including sandwich assays using monoclonal and/or polyclonal antibodies. Exemplary sandwich assays are described by David *et al.* in U.S. Patent Nos. 4,376,110 and 4,486,530, hereby incorporated by reference, and exemplified in Example 14.

Methods of Use: Drug Screening

This invention is particularly useful for screening compounds by using the BRCA1 polypeptide or binding fragment thereof in any of a variety of drug screening techniques.

The BRCA1 polypeptide or fragment employed in such a test may either be free in solution, affixed to a solid support, or borne on a cell surface. One method of drug screening utilizes eucaryotic or procaryotic host cells which are stably transformed with recombinant polynucleotides expressing the polypeptide or fragment, preferably in competitive binding assays. Such cells, either in viable or fixed form, can be used for standard binding assays. One may measure, for example, for the formation of complexes between a BRCA1 polypeptide or fragment and the agent being tested, or examine the degree to which the formation of a complex between a BRCA1 polypeptide or fragment and a known ligand is interfered with by the agent being tested.

Thus, the present invention provides methods of screening for drugs comprising contacting such an agent with a BRCA1 polypeptide or fragment thereof and assaying (i) for the presence of a complex between the agent and the BRCA1 polypeptide or fragment, or (ii) for the presence of a complex between the BRCA1 polypeptide or fragment and a ligand, by methods well known in the art. In such competitive binding assays the BRCA1 polypeptide or fragment is typically labeled.

Free BRCA1 polypeptide or fragment is separated from that present in a protein:protein complex,

and the amount of free (i.e., uncomplexed) label is a measure of the binding of the agent being tested to BRCA1 or its interference with BRCA1:ligand binding, respectively.

Another technique for drug screening provides high throughput screening for compounds having suitable binding affinity to the BRCA1 polypeptides and is described in detail in Geysen, PCT published application WO 84/03564, published on September 13, 1984. Briefly stated, large numbers of different small peptide test compounds are synthesized on a solid substrate, such as plastic pins or some other surface. The peptide test compounds are reacted with BRCA1 polypeptide and washed. Bound BRCA1 polypeptide is then detected by methods well known in the art.

Purified BRCA1 can be coated directly onto plates for use in the aforementioned drug screening techniques. However, non-neutralizing antibodies to the polypeptide can be used to capture antibodies to immobilize the BRCA1 polypeptide on the solid phase.

This invention also contemplates the use of competitive drug screening assays in which neutralizing antibodies capable of specifically binding the BRCA1 polypeptide compete with a test compound for binding to the BRCA1 polypeptide or fragments thereof. In this manner, the antibodies can be used to detect the presence of any peptide which shares one or more antigenic determinants of the BRCA1 polypeptide.

A further technique for drug screening involves the use of host eukaryotic cell lines or cells (such as described above) which have a nonfunctional BRCA1 gene. These host cell lines or cells are defective at the BRCA1 polypeptide level. The host cell lines or cells are grown in the presence of drug compound. The rate of growth of the host cells is measured to determine if the compound is capable of regulating the growth of BRCA1 defective cells.

Methods of Use: Rational Drug Design

The goal of rational drug design is to produce structural analogs of biologically active polypeptides of interest or of small molecules with which they interact (e.g., agonists, antagonists, inhibitors) in order to fashion drugs which are, for example, more active or stable forms of the polypeptide, or which, e.g., enhance or interfere with the function of a polypeptide *in vivo*. See, e.g., Hodgson, 1991. In one approach, one first determines the three-dimensional structure of a protein of interest (e.g., BRCA1 polypeptide) or, for example, of the BRCA1-receptor or ligand complex, by x-ray crystallography, by computer modeling or most typically, by a combination of

approaches. Less often, useful information regarding the structure of a polypeptide may be gained by modeling based on the structure of homologous proteins. An example of rational drug design is the development of HIV protease inhibitors (Erickson *et al.*, 1990). In addition, peptides (e.g., BRCA1 polypeptide) are analyzed by an alanine scan (Wells, 1991). In this technique, an amino acid residue is replaced by Ala, and its effect on the peptide's activity is determined. Each of the amino acid residues of the peptide is analyzed in this manner to determine the important regions of the peptide.

It is also possible to isolate a target-specific antibody, selected by a functional assay, and then to solve its crystal structure. In principle, this approach yields a pharmacore upon which subsequent drug design can be based. It is possible to bypass protein crystallography altogether by generating anti-idiotypic antibodies (anti-ids) to a functional, pharmacologically active antibody. As a mirror image of a mirror image, the binding site of the anti-ids would be expected to be an analog of the original receptor. The anti-id could then be used to identify and isolate peptides from banks of chemically or biologically produced banks of peptides. Selected peptides would then act as the pharmacore.

Thus, one may design drugs which have, e.g., improved BRCA1 polypeptide activity or stability or which act as inhibitors, agonists, antagonists, etc. of BRCA1 polypeptide activity. By virtue of the availability of cloned BRCA1 sequences, sufficient amounts of the BRCA1 polypeptide may be made available to perform such analytical studies as x-ray crystallography. In addition, the knowledge of the BRCA1 protein sequence provided herein will guide those employing computer modeling techniques in place of, or in addition to x-ray crystallography.

Methods of Use: Gene Therapy

According to the present invention, a method is also provided of supplying wild-type BRCA1 function to a cell which carries mutant BRCA1 alleles. Supplying such a function should suppress neoplastic growth of the recipient cells. The wild-type BRCA1 gene or a part of the gene may be introduced into the cell in a vector such that the gene remains extrachromosomal. In such a situation, the gene will be expressed by the cell from the extrachromosomal location. If a gene fragment is introduced and expressed in a cell carrying a mutant BRCA1 allele, the gene fragment should encode a part of the BRCA1 protein which is required for non-neoplastic growth of the cell. More preferred is the situation where the wild-type BRCA1 gene or a part thereof is introduced

into the mutant cell in such a way that it recombines with the endogenous mutant BRCA1 gene present in the cell. Such recombination requires a double recombination event which results in the correction of the BRCA1 gene mutation. Vectors for introduction of genes both for recombination and for extrachromosomal maintenance are known in the art, and any suitable vector may be used.

5 Methods for introducing DNA into cells such as electroporation, calcium phosphate co-precipitation and viral transduction are known in the art, and the choice of method is within the competence of the routineer. Cells transformed with the wild-type BRCA1 gene can be used as model systems to study cancer remission and drug treatments which promote such remission.

As generally discussed above, the BRCA1 gene or fragment, where applicable, may be
10 employed in gene therapy methods in order to increase the amount of the expression products of such genes in cancer cells. Such gene therapy is particularly appropriate for use in both cancerous and pre-cancerous cells, in which the level of BRCA1 polypeptide is absent or diminished compared to normal cells. It may also be useful to increase the level of expression of a given BRCA1 gene even in those tumor cells in which the mutant gene is expressed at a "normal" level,
15 but the gene product is not fully functional.

Gene therapy would be carried out according to generally accepted methods, for example, as described by Friedman, 1991. Cells from a patient's tumor would be first analyzed by the diagnostic methods described above, to ascertain the production of BRCA1 polypeptide in the tumor cells. A virus or plasmid vector (see further details below), containing a copy of the BRCA1
20 gene linked to expression control elements and capable of replicating inside the tumor cells, is prepared. Suitable vectors are known, such as disclosed in U.S. Patent 5,252,479 and PCT published application WO 93/07282. The vector is then injected into the patient, either locally at the site of the tumor or systemically (in order to reach any tumor cells that may have metastasized to other sites). If the transfected gene is not permanently incorporated into the genome of each of
25 the targeted tumor cells, the treatment may have to be repeated periodically.

Gene transfer systems known in the art may be useful in the practice of the gene therapy methods of the present invention. These include viral and nonviral transfer methods. A number of viruses have been used as gene transfer vectors, including papovaviruses, e.g., SV40 (Madzak *et al.*, 1992), adenovirus (Berkner, 1992; Berkner *et al.*, 1988; Gorziglia and Kapikian, 1992; Quantin
30 *et al.*, 1992; Rosenfeld *et al.*, 1992; Wilkinson *et al.*, 1992; Stratford-Perricaudet *et al.*, 1990), vaccinia virus (Moss, 1992), adeno-associated virus (Muzyczka, 1992; Ohi *et al.*, 1990),

herpesviruses including HSV and EBV (Margolskee, 1992; Johnson *et al.*, 1992; Fink *et al.*, 1992; Breakfield and Geller, 1987; Freese *et al.*, 1990), and retroviruses of avian (Bradyopadhyay and Temin, 1984; Petropoulos *et al.*, 1992), murine (Miller, 1992; Miller *et al.*, 1985; Sorge *et al.*, 1984; Mann and Baltimore, 1985; Miller *et al.*, 1988), and human origin (Shimada *et al.*, 1991; Helseth *et al.*, 1990; Page *et al.*, 1990; Buchschacher and Panganiban, 1992). Most human gene therapy protocols have been based on disabled murine retroviruses.

Nonviral gene transfer methods known in the art include chemical techniques such as calcium phosphate coprecipitation (Graham and van der Eb, 1973; Pellicer *et al.*, 1980); mechanical techniques, for example microinjection (Anderson *et al.*, 1980; Gordon *et al.*, 1980; Brinster *et al.*, 1981; Constantini and Lacy, 1981); membrane fusion-mediated transfer via liposomes (Felgner *et al.*, 1987; Wang and Huang, 1989; Kaneda *et al.*, 1989; Stewart *et al.*, 1992; Nabel *et al.*, 1990; Lim *et al.*, 1992); and direct DNA uptake and receptor-mediated DNA transfer (Wolff *et al.*, 1990; Wu *et al.*, 1991; Zenke *et al.*, 1990; Wu *et al.*, 1989b; Wolff *et al.*, 1991; Wagner *et al.*, 1990; Wagner *et al.*, 1991; Cotten *et al.*, 1990; Curiel *et al.*, 1991a; Curiel *et al.*, 1991b). Viral-mediated gene transfer can be combined with direct *in vivo* gene transfer using liposome delivery, allowing one to direct the viral vectors to the tumor cells and not into the surrounding nondividing cells. Alternatively, the retroviral vector producer cell line can be injected into tumors (Culver *et al.*, 1992). Injection of producer cells would then provide a continuous source of vector particles. This technique has been approved for use in humans with inoperable brain tumors.

In an approach which combines biological and physical gene transfer methods, plasmid DNA of any size is combined with a polylysine-conjugated antibody specific to the adenovirus hexon protein, and the resulting complex is bound to an adenovirus vector. The trimolecular complex is then used to infect cells. The adenovirus vector permits efficient binding, internalization, and degradation of the endosome before the coupled DNA is damaged.

Liposome/DNA complexes have been shown to be capable of mediating direct *in vivo* gene transfer. While in standard liposome preparations the gene transfer process is nonspecific, localized *in vivo* uptake and expression have been reported in tumor deposits, for example, following direct *in situ* administration (Nabel, 1992).

Gene transfer techniques which target DNA directly to breast and ovarian tissues, e.g., epithelial cells of the breast or ovaries, is preferred. Receptor-mediated gene transfer, for example,

is accomplished by the conjugation of DNA (usually in the form of covalently closed supercoiled plasmid) to a protein ligand via polylysine. Ligands are chosen on the basis of the presence of the corresponding ligand receptors on the cell surface of the target cell/tissue type. One appropriate receptor/ligand pair may include the estrogen receptor and its ligand, estrogen (and estrogen analogues). These ligand-DNA conjugates can be injected directly into the blood if desired and are directed to the target tissue where receptor binding and internalization of the DNA-protein complex occurs. To overcome the problem of intracellular destruction of DNA, coinfection with adenovirus can be included to disrupt endosome function.

The therapy involves two steps which can be performed singly or jointly. In the first step, prepubescent females who carry a BRCA1 susceptibility allele are treated with a gene delivery vehicle such that some or all of their mammary ductal epithelial precursor cells receive at least one additional copy of a functional normal BRCA1 allele. In this step, the treated individuals have reduced risk of breast cancer to the extent that the effect of the susceptible allele has been countered by the presence of the normal allele. In the second step of a preventive therapy, predisposed young females, in particular women who have received the proposed gene therapeutic treatment, undergo hormonal therapy to mimic the effects on the breast of a full term pregnancy.

Methods of Use: Peptide Therapy

Peptides which have BRCA1 activity can be supplied to cells which carry mutant or missing BRCA1 alleles. The sequence of the BRCA1 protein is disclosed (SEQ ID NO:2). Protein can be produced by expression of the cDNA sequence in bacteria, for example, using known expression vectors. Alternatively, BRCA1 polypeptide can be extracted from BRCA1-producing mammalian cells. In addition, the techniques of synthetic chemistry can be employed to synthesize BRCA1 protein. Any of such techniques can provide the preparation of the present invention which comprises the BRCA1 protein. The preparation is substantially free of other human proteins. This is most readily accomplished by synthesis in a microorganism or *in vitro*.

Active BRCA1 molecules can be introduced into cells by microinjection or by use of liposomes, for example. Alternatively, some active molecules may be taken up by cells, actively or by diffusion. Extracellular application of the BRCA1 gene product may be sufficient to affect tumor growth. Supply of molecules with BRCA1 activity should lead to partial reversal of the neoplastic state. Other molecules with BRCA1 activity (for example, peptides, drugs or organic

compounds) may also be used to effect such a reversal. Modified polypeptides having substantially similar function are also used for peptide therapy.

Methods of Use: Transformed Hosts

5 Similarly, cells and animals which carry a mutant BRCA1 allele can be used as model systems to study and test for substances which have potential as therapeutic agents. The cells are typically cultured epithelial cells. These may be isolated from individuals with BRCA1 mutations, either somatic or germline. Alternatively, the cell line can be engineered to carry the mutation in the BRCA1 allele, as described above. After a test substance is applied to the cells, the neoplas-
10 tically transformed phenotype of the cell is determined. Any trait of neoplastically transformed cells can be assessed, including anchorage-independent growth, tumorigenicity in nude mice, invasiveness of cells, and growth factor dependence. Assays for each of these traits are known in the art.

 Animals for testing therapeutic agents can be selected after mutagenesis of whole animals or
15 after treatment of germline cells or zygotes. Such treatments include insertion of mutant BRCA1 alleles, usually from a second animal species, as well as insertion of disrupted homologous genes. Alternatively, the endogenous BRCA1 gene(s) of the animals may be disrupted by insertion or deletion mutation or other genetic alterations using conventional techniques (Capecchi, 1989; Valancius and Smithies, 1991; Hasty *et al.*, 1991; Shinkai *et al.*, 1992; Mombaerts *et al.*, 1992;
20 Philpott *et al.*, 1992; Snouwaert *et al.*, 1992; Donehower *et al.*, 1992). After test substances have been administered to the animals, the growth of tumors must be assessed. If the test substance prevents or suppresses the growth of tumors, then the test substance is a candidate therapeutic agent for the treatment of the cancers identified herein. These animal models provide an extremely important testing vehicle for potential therapeutic products.

25

 The present invention is described by reference to the following Examples, which are offered by way of illustration and are not intended to limit the invention in any manner. Standard techniques well known in the art or the techniques specifically described below were utilized.

EXAMPLE 1**Ascertain and Study Kindreds Likely to Have
a 17q-Linked Breast Cancer Susceptibility Locus**

5 Extensive cancer prone kindreds were ascertained from a defined population providing a large set of extended kindreds with multiple cases of breast cancer and many relatives available to study. The large number of meioses present in these large kindreds provided the power to detect whether the BRCA1 locus was segregating, and increased the opportunity for informative recombinants to occur within the small region being investigated. This vastly improved the
10 chances of establishing linkage to the BRCA1 region, and greatly facilitated the reduction of the BRCA1 region to a manageable size, which permits identification of the BRCA1 locus itself.

Each kindred was extended through all available connecting relatives, and to all informative first degree relatives of each proband or cancer case. For these kindreds, additional breast cancer cases and individuals with cancer at other sites of interest (e.g. ovarian) who also appeared in the
15 kindreds were identified through the tumor registry linked files. All breast cancers reported in the kindred which were not confirmed in the Utah Cancer Registry were researched. Medical records or death certificates were obtained for confirmation of all cancers. Each key connecting individual and all informative individuals were invited to participate by providing a blood sample from which DNA was extracted. We also sampled spouses and relatives of deceased cases so that the genotype
20 of the deceased cases could be inferred from the genotypes of their relatives.

Ten kindreds which had three or more cancer cases with inferable genotypes were selected for linkage studies to 17q markers from a set of 29 kindreds originally ascertained from the linked databases for a study of proliferative breast disease and breast cancer (Skolnick *et al.*, 1990). The criterion for selection of these kindreds was the presence of two sisters or a mother and her
25 daughter with breast cancer. Additionally, two kindreds which have been studied since 1980 as part of our breast cancer linkage studies (K1001, K9018), six kindreds ascertained from the linked databases for the presence of clusters of breast and/or ovarian cancer (K2019, K2073, K2079, K2080, K2039, K2082) and a self-referred kindred with early onset breast cancer (K2035) were included. These kindreds were investigated and expanded in our clinic in the manner described
30 above. Table 1 displays the characteristics of these 19 kindreds which are the subject of subsequent examples. In Table 1, for each kindred the total number of individuals in our database,

the number of typed individuals, and the minimum, median, and maximum age at diagnosis of breast/ovarian cancer are reported. Kindreds are sorted in ascending order of median age at diagnosis of breast cancer. Four women diagnosed with both ovarian and breast cancer are counted in both categories.

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TABLE 1

Description of the 19 Kindreds

KINDRED	No. of Individuals	Breast				Ovarian			
		# Aff.	Age at Dx			# Aff.	Age at Dx		
			Min.	Med.	Max.		Min.	Med.	Max.
1910	15	4	27	34	49	-	-	-	-
1001	133	13	28	37	64	-	-	-	-
2035	42	8	28	37	45	1	-	60	-
2027	21	4	34	38	41	-	-	-	-
9018	54	9	30	40	72	2	46	48	50
1925	50	4	39	42	53	-	-	-	-
1927	49	5	32	42	51	-	-	-	-
1911	28	7	28	42	76	-	-	-	-
1929	16	4	34	43	73	-	-	-	-
1901	35	10	31	44	76	-	-	-	-
2082	180	20	27	47	67	10	45	52	66
2019	42	10	42	53	79	-	-	-	-
1900	70	8	45	55	70	1	-	78	-
2080	264	22+	27	55	92	4	45	53	71
2073	57	9	35	57	80	-	-	-	-
1917	16	4	43	58	61	-	-	-	-
1920	22	3	62	63	68	-	-	-	-
2079	136	14	38	66	84	4	52	59	65
2039	87	14	44	68	88	4	41	51	75

+ Includes one case of male breast cancer.

EXAMPLE 2**Selection of Kindreds Which are Linked to Chromosome 17q
and Localization of BRCA1 to the Interval Mfd15 - Mfd188**

5 For each sample collected in these 19 kindreds, DNA was extracted from blood (or in two cases from paraffin-embedded tissue blocks) using standard laboratory protocols. Genotyping in this study was restricted to short tandem repeat (STR) markers since, in general, they have high heterozygosity and PCR methods offer rapid turnaround while using very small amounts of DNA. To aid in this effort, four such STR markers on chromosome 17 were developed by screening a
10 chromosome specific cosmid library for CA positive clones. Three of these markers localized to the long arm: (46E6, Easton *et al.*, 1993); (42D6, Easton *et al.*, 1993); 26C2 (D17S514, Oliphant *et al.*, 1991), while the other, 12G6 (D17S513, Oliphant *et al.*, 1991), localized to the short arm near the p53 tumor suppressor locus. Two of these, 42D6 and 46E6, were submitted to the Breast Cancer Linkage Consortium for typing of breast cancer families by investigators worldwide.
15 Oligonucleotide sequences for markers not developed in our laboratory were obtained from published reports, or as part of the Breast Cancer Linkage Consortium, or from other investigators. All genotyping films were scored blindly with a standard lane marker used to maintain consistent coding of alleles. Key samples in the four kindreds presented here underwent duplicate typing for all relevant markers. All 19 kindreds have been typed for two polymorphic CA repeat markers:
20 42D6 (D17S588), a CA repeat isolated in our laboratory, and Mfd15 (D17S250), a CA repeat provided by J. Weber (Weber *et al.*, 1990). Several sources of probes were used to create genetic markers on chromosome 17, specifically chromosome 17 cosmid and lambda phage libraries created from sorted chromosomes by the Los Alamos National Laboratories (van Dilla *et al.*, 1986).
25 LOD scores for each kindred with these two markers (42D6, Mfd15) and a third marker, Mfd188 (D17S579, Hall *et al.*, 1992), located roughly midway between these two markers, were calculated for two values of the recombination fraction, 0.001 and 0.1. (For calculation of LOD scores, *see* Oh, 1985). Likelihoods were computed under the model derived by Claus *et al.*, 1991, which assumes an estimated gene frequency of 0.003, a lifetime risk in gene carriers of about 0.80,
30 and population based age-specific risks for breast cancer in non-gene carriers. Allele frequencies for the three markers used for the LOD score calculations were calculated from our own laboratory

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typings of unrelated individuals in the CEPH panel (White and Lalouel, 1988). Table 2 shows the results of the pairwise linkage analysis of each kindred with the three markers 42D6, Mfd188, and Mfd15.

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TABLE 2
Pairwise Linkage Analysis of Kindreds

KINDRED	Mfd15 (D17S250) Recombination	Mfd188 (D17S579) Recombination	42D6 (D17S588) Recombination
	0.001 0.1	0.001 0.1	0.001 0.1
1910	0.06	0.06	0.06
1001	-0.30	NT	-0.52
2035	2.34	0.94	2.34
2027	-1.22	-0.33	-1.16
9018	-0.54	-0.22	-0.33
1925	1.08	0.79	0.11
1927	-0.41	0.01	-0.11
			-0.07
			-0.02
1911	-0.27	-0.13	0.38
1929	-0.49	-0.25	-0.25
1901	1.50	1.17	0.37
2082	4.25	3.36	3.56
2019	-0.10	-0.01	-0.10
1900	-0.14	-0.11	-0.05
			-0.12
2080	-0.16	-0.04	-0.58
2073	-0.41	-0.29	-0.13
1917	-0.02	-0.02	0.00
1920	-0.03	-0.02	0.00
2079	0.02	0.01	0.01
2039	-1.67	-0.83	-1.15

NT - Kindred not typed for Mfd188.

Using a criterion for linkage to 17q of a LOD score > 1.0 for at least one locus under the CASH model (Claus *et al.*, 1991), four of the 19 kindreds appeared to be linked to 17q (K1901, K1925, K2035, K2082). A number of additional kindreds showed some evidence of linkage but at this time could not be definitively assigned to the linked category. These included kindreds K1911, K2073, K2039, and K2080. Three of the 17q-linked kindreds had informative recombinants in this region and these are detailed below.

Kindred 2082 is the largest 17q-linked breast cancer family reported to date by any group. The kindred contains 20 cases of breast cancer, and ten cases of ovarian cancer. Two cases have both ovarian and breast cancer. The evidence of linkage to 17q for this family is overwhelming; the LOD score with the linked haplotype is over 6.0, despite the existence of three cases of breast cancer which appear to be sporadic, i.e., these cases share no part of the linked haplotype between Mfd15 and 42D6. These three sporadic cases were diagnosed with breast cancer at ages 46, 47, and 54. In smaller kindreds, sporadic cancers of this type greatly confound the analysis of linkage and the correct identification of key recombinants. The key recombinant in the 2082 kindred is a woman who developed ovarian cancer at age 45 whose mother and aunt had ovarian cancer at ages 58 and 66, respectively. She inherited the linked portion of the haplotype for both Mfd188 and 42D6 while inheriting unlinked alleles at Mfd15; this recombinant event placed BRCA1 distal to Mfd15.

K1901 is typical of early-onset breast cancer kindreds. The kindred contains 10 cases of breast cancer with a median age at diagnosis of 43.5 years of age; four cases were diagnosed under age 40. The LOD score for this kindred with the marker 42D6 is 1.5, resulting in a posterior probability of 17q-linkage of 0.96. Examination of haplotypes in this kindred identified a recombinant haplotype in an obligate male carrier and his affected daughter who was diagnosed with breast cancer at age 45. Their linked allele for marker Mfd15 differs from that found in all other cases in the kindred (except one case which could not be completely inferred from her children). The two haplotypes are identical for Mfd188 and 42D6. Accordingly, data from Kindred 1901 would also place the BRCA1 locus distal to Mfd15.

Kindred 2035 is similar to K1901 in disease phenotype. The median age of diagnosis for the eight cases of breast cancer in this kindred is 37. One case also had ovarian cancer at age 60. The breast cancer cases in this family descend from two sisters who were both unaffected with breast cancer until their death in the eighth decade. Each branch contains four cases of breast cancer with

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at least one case in each branch having markedly early onset. This kindred has a LOD score of 2.34 with Mfd15. The haplotypes segregating with breast cancer in the two branches share an identical allele at Mfd15 but differ for the distal loci Mfd188 and NM23 (a marker typed as part of the consortium which is located just distal to 42D6 (Hall *et al.*, 1992)). Although the two haplotypes are concordant for marker 42D6, it is likely that the alleles are shared identical by state (the same allele but derived from different ancestors), rather than identical by descent (derived from a common ancestor) since the shared allele is the second most common allele observed at this locus. By contrast the linked allele shared at Mfd15 has a frequency of 0.04. This is a key recombinant in our dataset as it is the sole recombinant in which BRCA1 segregated with the proximal portion of the haplotype, thus setting the distal boundary to the BRCA1 region. For this event not to be a key recombinant requires that a second mutant BRCA1 gene be present in a spouse marrying into the kindred who also shares the rare Mfd15 allele segregating with breast cancer in both branches of the kindred. This event has a probability of less than one in a thousand. The evidence from this kindred therefore placed the BRCA1 locus proximal to Mfd188.

EXAMPLE 3

Creation of a Fine Structure Map and Refinement of the BRCA1 Region to Mfd191-Mfd188 using Additional STR Polymorphisms

In order to improve the characterization of our recombinants and define closer flanking markers, a dense map of this relatively small region on chromosome 17q was required. The chromosome 17 workshop has produced a consensus map of this region (Figure 1) based on a combination of genetic and physical mapping studies (Fain, 1992). This map contains both highly polymorphic STR polymorphisms, and a number of nonpolymorphic expressed genes. Because this map did not give details on the evidence for this order nor give any measure of local support for inversions in the order of adjacent loci, we viewed it as a rough guide for obtaining resources to be used for the development of new markers and construction of our own detailed genetic and physical map of a small region containing BRCA1. Our approach was to analyze existing STR markers provided by other investigators and any newly developed markers from our laboratory with respect to both a panel of meiotic (genetic) breakpoints identified using DNA from the CEPH

reference families and a panel of somatic cell hybrids (physical breakpoints) constructed for this region. These markers included 26C2 developed in our laboratory which maps proximal to Mfd15, Mfd191 (provided by James Weber), THRA1 (Futreal *et al.*, 1992a), and three polymorphisms kindly provided to us by Dr. Donald Black, NM23 (Hall *et al.* 1992), SCG40 (D17S181), and 6C1 (D17S293).

Genetic localization of markers. In order to localize new markers genetically within the region of interest, we have identified a number of key meiotic breakpoints within the region, both in the CEPH reference panel and in our large breast cancer kindred (K2082). Given the small genetic distance in this region, they are likely to be only a relatively small set of recombinants which can be used for this purpose, and they are likely to group markers into sets. The orders of the markers within each set can only be determined by physical mapping. However the number of genotypings necessary to position a new marker is minimized. These breakpoints are illustrated in Tables 3 and 4. Using this approach we were able to genetically order the markers THRA1, 6C1, SCG40, and Mfd191. As can be seen from Tables 3 and 4, THRA1 and MFD191 both map inside the Mfd15-Mfd188 region we had previously identified as containing the BRCA1 locus. In Tables 3 and 4, M/P indicates a maternal or paternal recombinant. A "1" indicates inherited allele is of grandpaternal origin, while a "0" indicates grandmaternal origin, and "-" indicates that the locus was untyped or uninformative.

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TABLE 3
CEPH Recombinants

<u>Family</u>	<u>ID</u>	<u>M/P</u>	<u>Mfd15</u>	<u>THRA1</u>	<u>Mfd191</u>	<u>Mfd188</u>	<u>SCG40</u>	<u>_6Cl_</u>	<u>42D6</u>
13292	4	M	1	1	1	0	0	0	0
13294	4	M	1	1	1	0	0	0	0
13294	6	M	0	0	1	1	-	-	-
1334	3	M	1	1	1	1	1	0	0
1333	4	M	1	1	1	0	-	-	0
1333	6	M	0	0	1	1	-	-	1
1333	8	P	1	0	0	0	-	-	0
1377	8	M	0	-	0	0	0	0	1

TABLE 4
Kindred 2082 Recombinants

<u>Family</u>	<u>ID</u>	<u>M/P</u>	<u>Mfd15</u>	<u>Mfd191</u>	<u>Mfd188</u>	<u>SCG40</u>	<u>6C1</u>	<u>42D6</u>
75		M	0	1	1	1	-	-
63		M	0	0	1	1	-	1
125		M	1	1	1	0	-	0
40		M	1	1	0	0	-	0

Analysis of markers Mfd15, Mfd188, Mfd191, and THRA1 in our recombinant families.

Mfd15, Mfd188, Mfd191 and THRA1 were typed in our recombinant families and examined for additional information to localize the BRCA1 locus. In kindred 1901, the Mfd15 recombinant was recombinant for THRA1 but uninformative for Mfd191, thus placing BRCA1 distal to THRA1. In
5 K2082, the recombinant with Mfd15 also was recombinant with Mfd191, thus placing the BRCA1 locus distal to Mfd191 (Goldgar *et al.*, 1994). Examination of THRA1 and Mfd191 in kindred K2035 yielded no further localization information as the two branches were concordant for both markers. However, SCG40 and 6C1 both displayed the same pattern as Mfd188, thus increasing our confidence in the localization information provided by the Mfd188 recombinant in this family.
10 The BRCA1 locus, or at least a portion of it, therefore lies within an interval bounded by Mfd191 on the proximal side and Mfd188 on the distal side.

EXAMPLE 4

Development of Genetic and Physical
Resources in the Region of Interest

To increase the number of highly polymorphic loci in the Mfd191-Mfd188 region, we developed a number of STR markers in our laboratory from cosmids and YACs which physically map to the region. These markers allowed us to further refine the region.

20 STSs were identified from genes known to be in the desired region to identify YACs which contained these loci, which were then used to identify subclones in cosmids, P1s or BACs. These subclones were then screened for the presence of a CA tandem repeat using a (CA)_n oligonucleotide (Pharmacia). Clones with a strong signal were selected preferentially, since they were more likely to represent CA-repeats which have a large number of repeats and/or are of near-
25 perfect fidelity to the (CA)_n pattern. Both of these characteristics are known to increase the probability of polymorphism (Weber, 1990). These clones were sequenced directly from the vector to locate the repeat. We obtained a unique sequence on one side of the CA-repeat by using one of a set of possible primers complementary to the end of a CA-repeat, such as (GT)₁₀T. Based on this unique sequence, a primer was made to sequence back across the repeat in the other
30 direction, yielding a unique sequence for design of a second primer flanking the CA-repeat. STRs were then screened for polymorphism on a small group of unrelated individuals and tested against

the hybrid panel to confirm their physical localization. New markers which satisfied these criteria were then typed in a set of 40 unrelated individuals from the Utah and CEPH families to obtain allele frequencies appropriate for the study population. Many of the other markers reported in this study were tested in a smaller group of CEPH unrelated individuals to obtain similarly appropriate allele frequencies.

Using the procedure described above, a total of eight polymorphic STRs was found from these YACS. Of the loci identified in this manner, four were both polymorphic and localized to the BRCA1 region. Four markers did not localize to chromosome 17, reflecting the chimeric nature of the YACs used. The four markers which were in the region were denoted AA1, ED2, 4-7, and YM29. AA1 and ED2 were developed from YACs positive for the RNU2 gene, 4-7 from an EPB3 YAC and YM29 from a cosmid which localized to the region by the hybrid panel. A description of the number of alleles, heterozygosity and source of these four and all other STR polymorphisms analyzed in the breast cancer kindreds is given below in Table 5.

TABLE 5
Polymorphic Short Tandem Repeat Markers Used
for Fine Structure Mapping of the BRCA1 Locus

Clone	Gene	Na**	Hetero- zygosity	Allele Frequency (%)					
				1	2	3	4	5	6
Mfd15	D17S250	10	0.82	26	22	15	7	7	23
THRA1	THRA1	5							
Mfd191	D17S776	7	0.55	48	20	11	7	7	7
ED2	D17S1327	12	0.55	62	9	8	5	5	11
AA1	D17S1326	7	0.83	28	28	25	8	6	5
CA375	D17S184	10	0.75	26	15	11	9	9	20
4-7	D17S1183	9	0.50	63	15	8	6	4	4
YM29	--	9	0.62	42	24	12	7	7	8
Mfd188	D17S579	12	0.92	33	18	8	8	8	25
SCG40	D17S181	14	0.90	20	18	18	10	8	35
42D6	D17S588	11	0.86	21	17	11	10	9	32
6C1	D17S293	7	0.75	30	30	11	11	9	9
Z109	D17S750	9	0.70	33	27	7	7	7	19
tdj1475	D17S1321	13	0.84	21	16	11	11	8	33
CF4	D17S1320	6	0.63	50	27	9	7	4	3
tdj1239	D17S1328	10	0.80	86	10	9	7	4	14
U5	D17S1325	13	0.83	19	16	12	10	9	34

* Allele codes 1-5 are listed in decreasing frequency; allele numbers do not correspond to fragment sizes. Allele 6 frequency is the joint frequency of all other alleles for each locus.

** Number of alleles seen in the genetically independent DNA samples used for calculating allele frequencies.

The four STR polymorphisms which mapped physically to the region (4-7, ED2, AA1, YM29) were analyzed in the meiotic, breakpoint panel shown initially in Tables 3 and 4. Tables 6 and 7 contain the relevant CEPH data and Kindred 2082 data for localization of these four markers.

5 In the tables, M/P indicates a maternal or paternal recombinant. A "1" indicates inherited allele is of grandpaternal origin, while a "0" indicates grandmaternal origin, and "-" indicates that the locus was untyped or uninformative.

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TABLE 6
Key Recombinants Used for Genetic
Ordering of New STR Loci Developed in
Our Laboratory Within the BRCA1 Region of 17q

CEPH Family	ID	M/P	Mfd15	THRA1	Mfd191	ED2	AA1	Z109	4-7	YM29	Mfd188	SCG40	42D6
13292	4	M	1	1	1	1	1	0	0	0	0	0	0
13294	4	M	1	0	0	-	0	-	-	-	0	-	-
13294	6	M	0	0	1	-	1	-	-	-	1	-	-
1333	4	M	1	1	1	-	0	-	-	0	0	-	0
1333	6	M	0	0	1	-	1	-	-	1	1	-	1
1333	3	M	0	0	1	-	-	-	1	1	1	-	1

TABLE 7

Kindred 2082 Recombinants

ID	M/P	Mfd15	Mfd191	ED2	AA1	4-7	YM29	Mfd188	SCG40	42D6
63	M	0	0	1	-	1	1	1	1	1
125	M	1	1	1	-	1	1	1	0	0
40	M	1	1	0	-	0	-	0	0	0
22	P	0	0	1	1	1	1	1	1	1

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From CEPH 1333-04, we see that AA1 and YM29 must lie distal to Mfd191. From 13292, it can be inferred that both AA1 and ED2 are proximal to 4-7, YM29, and Mfd188. The recombinants found in K2082 provide some additional ordering information. Three independent observations (individual numbers 22, 40, & 63) place AA1, ED2, 4-7, and YM29, and Mfd188 distal to Mfd191, while ID 125 places 4-7, YM29, and Mfd188 proximal to SCG40. No genetic information on the relative ordering within the two clusters of markers AA1/ED2 and 4-7/YM29/Mfd188 was obtained from the genetic recombinant analysis. Although ordering loci with respect to hybrids which are known to contain "holes" in which small pieces of interstitial human DNA may be missing is problematic, the hybrid patterns indicate that 4-7 lies above both YM29 and Mfd188.

10

EXAMPLE 5

Genetic Analyses of Breast Cancer Kindreds with Markers AA1, 4-7, ED2, and YM29

15 In addition to the three kindreds containing key recombinants which have been discussed previously, kindred K2039 was shown through analysis of the newly developed STR markers to be linked to the region and to contain a useful recombinant.

Table 8 defines the haplotypes (shown in coded form) of the kindreds in terms of specific marker alleles at each locus and their respective frequencies. In Table 8, alleles are listed in descending order of frequency; frequencies of alleles 1-5 for each locus are given in Table 5. Haplotypes coded H are BRCA1 associated haplotypes, P designates a partial H haplotype, and an R indicates an observable recombinant haplotype. As evident in Table 8, not all kindreds were typed for all markers; moreover, not all individuals within a kindred were typed for an identical set of markers, especially in K2082. With one exception, only haplotypes inherited from affected or at-risk kindred members are shown; haplotypes from spouses marrying into the kindred are not described. Thus in a given sibship, the appearance of haplotypes X and Y indicates that both haplotypes from the affected/at-risk individual were seen and neither was a breast cancer associated haplotype.

20

25

TABLE 8

Breast Cancer Linked Haplotypes
Found in the Three Kindreds

Kin. HAP	Mfd 15	THRA1	Mfd 191	tdj 1475	ED2	AA1	Z109	CA375	4-7	YM29	Mfd 188	SCG40	6C1	42D6
1901 H1	1	5	5	3	1	4	NI	NI	1	1	3	NI	NI	1
R2	9	2	5	6	1	4	NI	NI	1	1	3	NI	NI	1
2082 H1	3	NI	4	6	6	1	NI	NI	2	1	4	2	NI	1
P1	3	NI	4	NI	NI	NI	NI	NI	NI	NI	4	2	NI	1
P2	3	NI	NI	NI	NI	NI	NI	NI	NI	NI	4	NI	NI	NI
R1	6	NI	1	5	6	1	NI	NI	2	1	4	2	NI	1
R2	6	NI	4	6	6	1	NI	NI	2	1	4	2	NI	1
R3	3	NI	4	NI	6	1	NI	NI	2	1	4	1	NI	7
R4	7	NI	1	NI	1	5	NI	NI	4	6	1	2	NI	1
R5	3	NI	4	NI	NI	NI	NI	NI	NI	2	1	NI	NI	NI
R6	3	NI	4	3	1	2	NI	NI	1	2	2	6	NI	6
R7	3	NI	4	3	7	1	NI	NI	1	1	3	7	NI	4
2035 H1	8	2	1	NI	5	1	1	4	3	1	6	8	2	4
H2	8	2	1	NI	5	1	1	2	1	1	2	3	1	4
R2	8	2	1	NI	5	1	1	2	1	1	2	3	6	1

In kindred K1901, the new markers showed no observable recombination with breast cancer susceptibility, indicating that the recombination event in this kindred most likely took place between THRA1 and ED2. Thus, no new BRCA1 localization information was obtained based upon studying the four new markers in this kindred. In kindred 2082 the key recombinant individual has inherited the linked alleles for ED2, 4-7, AA1, and YM29, and was recombinant for tdj1474 indicating that the recombination event occurred in this individual between tdj1474 and ED2/AA1.

There are three haplotypes of interest in kindred K2035, H1, H2, and R2 shown in Table 8. H1 is present in the four cases and one obligate male carrier descendant from individual 17 while H2 is present or inferred in two cases and two obligate male carriers in descendants of individual 10. R2 is identical to H2 for loci between and including Mfd15 and SCG40, but has recombined between SCG40 and 42D6. Since we have established that BRCA1 is proximal to 42D6, this H2/R2 difference adds no further localization information. H1 and R2 share an identical allele at Mfd15, THRA1, AA1, and ED2 but differ for loci presumed distal to ED2, i.e., 4-7, Mfd188, SCG40, and 6C1. Although the two haplotypes are concordant for the 5th allele for marker YM29, a marker which maps physically between 4-7 and Mfd188, it is likely that the alleles are shared identical by state rather than identical by descent since this allele is the most common allele at this locus with a frequency estimated in CEPH parents of 0.42. By contrast, the linked alleles shared at the Mfd15 and ED2 loci have frequencies of 0.04 and 0.09, respectively. They also share more common alleles at Mfd191 (frequency = 0.52), THRA1, and AA1 (frequency = 0.28). This is the key recombinant in the set as it is the sole recombinant in which breast cancer segregated with the proximal portion of the haplotype, thus setting the distal boundary. The evidence from this kindred therefore places the BRCA1 locus proximal to 4-7.

The recombination event in kindred 2082 which places BRCA1 distal to tdj1474 is the only one of the four events described which can be directly inferred; that is, the affected mother's genotype can be inferred from her spouse and offspring, and the recombinant haplotype can be seen in her affected daughter. In this family the odds in favor of affected individuals carrying BRCA1 susceptibility alleles are extremely high; the only possible interpretations of the data are that BRCA1 is distal to Mfd191 or alternatively that the purported recombinant is a sporadic case of ovarian cancer at age 44. Rather than a directly observable or inferred recombinant, interpretation of kindred 2035 depends on the observation of distinct 17q-haplotypes segregating in

different and sometimes distantly related branches of the kindred. The observation that portions of these haplotypes have alleles in common for some markers while they differ at other markers places the BRCA1 locus in the shared region. The confidence in this placement depends on several factors: the relationship between the individuals carrying the respective haplotypes, the frequency of the shared allele, the certainty with which the haplotypes can be shown to segregate with the BRCA1 locus, and the density of the markers in the region which define the haplotype. In the case of kindred 2035, the two branches are closely related, and each branch has a number of early onset cases which carry the respective haplotype. While two of the shared alleles are common, (Mfd191, THRA1), the estimated frequencies of the shared alleles at Mfd15, AA1, and ED2 are 0.04, 0.28, and 0.09, respectively. It is therefore highly likely that these alleles are identical by descent (derived from a common ancestor) rather than identical by state (the same allele but derived from the general population).

EXAMPLE 6

Refined Physical Mapping Studies Place the BRCA1 Gene in a Region Flanked by tdj1474 and U5R

Since its initial localization to chromosome 17q in 1990 (Hall *et al.*, 1990) a great deal of effort has gone into localizing the BRCA1 gene to a region small enough to allow implementation of effective positional cloning strategies to isolate the gene. The BRCA1 locus was first localized to the interval Mfd15 (D17S250) - 42D6 (D17S588) by multipoint linkage analysis (Easton *et al.*, 1993) in the collaborative Breast Cancer Linkage Consortium dataset consisting of 214 families collected worldwide. Subsequent refinements of the localization have been based upon individual recombinant events in specific families. The region THRA1 - D17S183 was defined by Bowcock *et al.*, 1993; and the region THRA1 - D17S78 was defined by Simard *et al.*, 1993.

We further showed that the BRCA1 locus must lie distal to the marker Mfd191 (D17S776) (Goldgar *et al.*, 1994). This marker is known to lie distal to THRA1 and RARA. The smallest published region for the BRCA1 locus is thus between D17S776 and D17S78. This region still contains approximately 1.5 million bases of DNA, making the isolation and testing of all genes in the region a very difficult task. We have therefore undertaken the tasks of constructing a physical map of the region, isolating a set of polymorphic STR markers located in the region, and analyzing

these new markers in a set of informative families to refine the location of the BRCA1 gene to a manageable interval.

Four families provide important genetic evidence for localization of BRCA1 to a sufficiently small region for the application of positional cloning strategies. Two families (K2082, K1901) provide data relating to the proximal boundary for BRCA1 and the other two (K2035, K1813) fix the distal boundary. These families are discussed in detail below. A total of 15 Short Tandem Repeat markers assayable by PCR were used to refine this localization in the families studied. These markers include DS17S7654, DS17S975, tdj1474, and tdj1239. Primer sequences for these markers are provided in SEQ ID NO:3 and SEQ ID NO:4 for DS17S754; in SEQ ID NO:5 and SEQ ID NO:6 for DS17S975; in SEQ ID NO:7 and SEQ ID NO:8 for tdj1474; and, in SEQ ID NO:9 and SEQ ID NO:10 for tdj1239.

Kindred 2082

Kindred 2082 is the largest BRCA1-linked breast/ovarian cancer family studied to date. It has a LOD score of 8.6, providing unequivocal evidence for 17q linkage. This family has been previously described and shown to contain a critical recombinant placing BRCA1 distal to MFD191 (D17S776). This recombinant occurred in a woman diagnosed with ovarian cancer at age 45 whose mother had ovarian cancer at age 63. The affected mother was deceased; however, from her children, she could be inferred to have the linked haplotype present in the 30 other linked cases in the family in the region between Mfd15 and Mfd188. Her affected daughter received the linked allele at the loci ED2, 4-7, and Mfd188, but received the allele on the non-BRCA1 chromosome at Mfd15 and Mfd191. In order to further localize this recombination breakpoint, we tested the key members of this family for the following markers derived from physical mapping resources: tdj1474, tdj1239, CF4, D17S855. For the markers tdj1474 and CF4, the affected daughter did not receive the linked allele. For the STR locus tdj1239, however, the mother could be inferred to be informative and her daughter did receive the BRCA1-associated allele. D17S855 was not informative in this family. Based on this analysis, the order is 17q centromere - Mfd191 - 17HSD - CF4 - tdj1474 - tdj1239 - D17S855 - ED2 - 4-7 - Mfd188 - 17q telomere. The recombinant described above therefore places BRCA1 distal to tdj1474, and the breakpoint is localized to the interval between tdj1474 and tdj1239. The only alternative explanation for the data in this family other than that of BRCA1 being located distal to tdj1474, is that the ovarian cancer present in the

recombinant individual is caused by reasons independent of the BRCA1 gene. Given that ovarian cancer diagnosed before age 50 is rare, this alternate explanation is exceedingly unlikely.

Kindred 1901

5 Kindred 1901 is an early-onset breast cancer family with 7 cases of breast cancer diagnosed before 50, 4 of which were diagnosed before age 40. In addition, there were three cases of breast cancer diagnosed between the ages of 50 and 70. One case of breast cancer also had ovarian cancer at age 61. This family currently has a LOD score of 1.5 with D17S855. Given this linkage evidence and the presence of at least one ovarian cancer case, this family has a posterior probability of being
10 due to BRCA1 of over 0.99. In this family, the recombination comes from the fact that an individual who is the brother of the ovarian cancer case from which the majority of the other cases descend, only shares a portion of the haplotype which is cosegregating with the other cases in the family. However, he passed this partial haplotype to his daughter who developed breast cancer at age 44. If this case is due to the BRCA1 gene, then only the part of the haplotype shared between
15 this brother and his sister can contain the BRCA1 gene. The difficulty in interpretation of this kind of information is that while one can be sure of the markers which are not shared and therefore recombinant, markers which are concordant can either be shared because they are non-recombinant, or because their parent was homozygous. Without the parental genotypic data it is impossible to discriminate between these alternatives. Inspection of the haplotype in K1901,
20 shows that he does not share the linked allele at Mfd15 (D17S250), THRA1, CF4 (D17S1320), and tdj1474 (D17S1321). He does share the linked allele at Mfd191 (D17S776), ED2 (D17S1327), tdj1239 (D17S1328), and Mfd188 (D17S579). Although the allele shared at Mfd191 is relatively rare (0.07), we would presume that the parent was homozygous since they are recombinant with markers located nearby on either side, and a double recombination event in this region would be
25 extremely unlikely. Thus the evidence in this family would also place the BRCA1 locus distal to tdj1474. However, the lower limit of this breakpoint is impossible to determine without parental genotype information. It is intriguing that the key recombinant breakpoint in this family confirms the result in Kindred 2082. As before, the localization information in this family is only meaningful if the breast cancer was due to the BRCA1 gene. However, her relatively early age at
30 diagnosis (44) makes this seem very likely since the risk of breast cancer before age 45 in the general population is low (approximately 1%).

Kindred 2035

This family is similar to K1901 in that the information on the critical recombinant events is not directly observed but is inferred from the observation that the two haplotypes which are cosegregating with the early onset breast cancer in the two branches of the family appear identical for markers located in the proximal portion of the 17q BRCA1 region but differ at more distal loci. Each of these two haplotypes occurs in at least four cases of early-onset or bilateral breast cancer. The overall LOD score with ED2 in this family is 2.2, and considering that there is a case of ovarian cancer in the family (indicating a prior probability of BRCA1 linkage of 80%), the resulting posterior probability that this family is linked to BRCA1 is 0.998. The haplotypes are identical for the markers Mfd15, THRA1, Mfd191, ED2, AA1, D17S858 and D17S902. The common allele at Mfd15 and ED2 are both quite rare, indicating that this haplotype is shared identical by descent. The haplotypes are discordant, however, for CA375, 4-7, and Mfd188, and several more distal markers. This indicates that the BRCA1 locus must lie above the marker CA-375. This marker is located approximately 50 kb below D17S78, so it serves primarily as additional confirmation of this previous lower boundary as reported in Simard *et al.* (1993).

Kindred 1813

Kindred 1813 is a small family with four cases of breast cancer diagnosed under the age of 40 whose mother had breast cancer diagnosed at age 45 and ovarian cancer at age 61. This situation is somewhat complicated by the fact the four cases appear to have three different fathers, only one of whom has been genotyped. However, by typing a number of different markers in the BRCA1 region as well as highly polymorphic markers elsewhere in the genome, the paternity of all children in the family has been determined with a high degree of certainty. This family yields a maximum multipoint LOD score of 0.60 with 17q markers and, given that there is at least one case of ovarian cancer, results in a posterior probability of being a BRCA1 linked family of 0.93. This family contains a directly observable recombination event in individual 18 (see Figure 5 in Simard *et al.*, *Human Mol. Genet.* 2:1193-1199 (1993)), who developed breast cancer at age 34. The genotype of her affected mother at the relevant 17q loci can be inferred from her genotypes, her affected sister's genotypes, and the genotypes of three other unaffected siblings. Individual 18 inherits the BRCA1-linked alleles for the following loci: Mfd15, THRA1, D17S800, D17S855,

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AA1, and D17S931. However, for markers below D17S931, i.e., U5R, vrs31, D17S858, and D17S579, she has inherited the alleles located on the non-disease bearing chromosome. The evidence from this family therefore would place the BRCA1 locus proximal to the marker U5R. Because of her early age at diagnosis (34) it is extremely unlikely that the recombinant individual's cancer is not due to the gene responsible for the other cases of breast/ovarian cancer in this family; the uncertainty in this family comes from our somewhat smaller amount of evidence that breast cancer in this family is due to BRCA1 rather than a second, as yet unmapped, breast cancer susceptibility locus.

Size of the region containing BRCA1

Based on the genetic data described in detail above, the BRCA1 locus must lie in the interval between the markers tdj1474 and U5R, both of which were isolated in our laboratory. Based upon the physical maps shown in Figures 2 and 3, we can try to estimate the physical distance between these two loci. It takes approximately 14 P1 clones with an average insert size of approximately 80 kb to span the region. However, because all of these P1s overlap to some unknown degree, the physical region is most likely much smaller than 14 times 80 kb. Based on restriction maps of the clones covering the region, we estimate the size of the region containing BRCA1 to be approximately 650 kb.

EXAMPLE 7

Identification of Candidate cDNA Clones for the BRCA1 Locus by Genomic Analysis of the Contig Region

Complete screen of the plausible region. The first method to identify candidate cDNAs, although labor intensive, used known techniques. The method comprised the screening of cosmid and P1 and BAC clones in the contig to identify putative coding sequences. The clones containing putative coding sequences were then used as probes on filters of cDNA libraries to identify candidate cDNA clones for future analysis. The clones were screened for putative coding sequences by either of two methods.

Zoo blots. The first method for identifying putative coding sequences was by screening the cosmid and P1 clones for sequences conserved through evolution across several species. This

technique is referred to as "zoo blot analysis" and is described by Monaco, 1986. Specifically, DNAs from cow, chicken, pig, mouse and rat were digested with the restriction enzymes EcoRI and HindIII (8 µg of DNA per enzyme). The digested DNAs were separated overnight on an 0.7% gel at 20 volts for 16 hours (14 cm gel), and the DNA transferred to Nylon membranes using standard Southern blot techniques. For example, the zoo blot filter was treated at 65°C in 0.1 x SSC, 0.5% SDS, and 0.2M Tris, pH 8.0, for 30 minutes and then blocked overnight at 42°C in 5x SSC, 10% PEG 8000, 20 mM NaPO₄ pH 6.8, 100 µg/ml Salmon Sperm DNA, 1x Denhardt's, 50% formamide, 0.1% SDS, and 2 µg/ml C₀t-1 DNA.

The cosmid and Pl clones to be analyzed were digested with a restriction enzyme to release the human DNA from the vector DNA. The DNA was separated on a 14 cm, 0.5% agarose gel run overnight at 20 volts for 16 hours. The human DNA bands were cut out of the gel and electroeluted from the gel wedge at 100 volts for at least two hours in 0.5x Tris Acetate buffer (Maniatis *et al.*, 1982). The eluted Not I digested DNA (~15 kb to 25 kb) was then digested with EcoRI restriction enzyme to give smaller fragments (~0.5 kb to 5.0 kb) which melt apart more easily for the next step of labeling the DNA with radionucleotides. The DNA fragments were labeled by means of the hexamer random prime labeling method (Boehringer-Mannheim, Cat. #1004760). The labeled DNA was spermine precipitated (add 100 µl TE, 5 µl 0.1 M spermine, and 5 µl of 10 mg/ml salmon sperm DNA) to remove unincorporated radionucleotides. The labeled DNA was then resuspended in 100 µl TE, 0.5 M NaCl at 65°C for 5 minutes and then blocked with Human C₀t-1 DNA for 2-4 hrs. as per the manufacturer's instructions (Gibco/BRL, Cat. #5279SA). The C₀t-1 blocked probe was incubated on the zoo blot filters in the blocking solution overnight at 42°C. The filters were washed for 30 minutes at room temperature in 2 x SSC, 0.1% SDS, and then in the same buffer for 30 minutes at 55°C. The filters were then exposed 1 to 3 days at -70°C to Kodak XAR-5 film with an intensifying screen. Thus, the zoo blots were hybridized with either the pool of Eco-RI fragments from the insert, or each of the fragments individually.

HTF island analysis. The second method for identifying cosmids to use as probes on the cDNA libraries was HTF island analysis. Since the pulsed-field map can reveal HTF islands, cosmids that map to these HTF island regions were analyzed with priority. HTF islands are segments of DNA which contain a very high frequency of unmethylated CpG dinucleotides (Tonolio *et al.*, 1990) and are revealed by the clustering of restriction sites of enzymes whose

recognition sequences include CpG dinucleotides. Enzymes known to be useful in HTF-island analysis are *AscI*, *NotI*, *BssHII*, *EagI*, *SacII*, *NaeI*, *NarI*, *SmaI*, and *MluI* (Anand, 1992). A pulsed-field map was created using the enzymes *NotI*, *NruI*, *EagI*, *SacII*, and *Sall*, and two HTF islands were found. These islands are located in the distal end of the region, one being distal to the GP2B locus, and the other being proximal to the same locus, both outside the BRCA1 region. The cosmids derived from the YACs that cover these two locations were analyzed to identify those that contain these restriction sites, and thus the HTF islands.

cDNA screening. Those clones that contain HTF islands or show hybridization to other species DNA besides human are likely to contain coding sequences. The human DNA from these clones was isolated as whole insert or as *EcoRI* fragments and labeled as described above. The labeled DNA was used to screen filters of various cDNA libraries under the same conditions as the zoo blots except that the cDNA filters undergo a more stringent wash of 0.1 x SSC, 0.1% SDS at 65°C for 30 minutes twice.

Most of the cDNA libraries used to date in our studies (libraries from normal breast tissue, breast tissue from a woman in her eighth month of pregnancy and a breast malignancy) were prepared at Clontech, Inc. The cDNA library generated from breast tissue of an 8 month pregnant woman is available from Clontech (Cat. #HL1037a) in the Lambda gt-10 vector, and is grown in C600Hfl bacterial host cells. Normal breast tissue and malignant breast tissue samples were isolated from a 37 year old Caucasian female and one-gram of each tissue was sent to Clontech for mRNA processing and cDNA library construction. The latter two libraries were generated using both random and oligo-dT priming, with size selection of the final products which were then cloned into the Lambda Zap II vector, and grown in XL1-blue strain of bacteria as described by the manufacturer. Additional tissue-specific cDNA libraries include human fetal brain (Stratagene, Cat. 936206), human testis (Clontech Cat. HL3024), human thymus (Clontech Cat. HL1127n), human brain (Clontech Cat. HL11810), human placenta (Clontech Cat 1075b), and human skeletal muscle (Clontech Cat. HL1124b).

The cDNA libraries were plated with their host cells on NZCYM plates, and filter lifts are made in duplicate from each plate as per Maniatis *et al.* (1982). Insert (human) DNA from the candidate genomic clones was purified and radioactively labeled to high specific activity. The radioactive DNA was then hybridized to the cDNA filters to identify those cDNAs which correspond to genes located within the candidate cosmid clone. cDNAs identified by this method

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were picked, replated, and screened again with the labeled clone insert or its derived EcoRI fragment DNA to verify their positive status. Clones that were positive after this second round of screening were then grown up and their DNA purified for Southern blot analysis and sequencing. Clones were either purified as plasmid through *in vivo* excision of the plasmid from the Lambda
5 vector as described in the protocols from the manufacturers, or isolated from the Lambda vector as a restriction fragment and subcloned into plasmid vector.

The Southern blot analysis was performed in duplicate, one using the original genomic insert DNA as a probe to verify that cDNA insert contains hybridizing sequences. The second blot was hybridized with cDNA insert DNA from the largest cDNA clone to identify which clones represent
10 the same gene. All cDNAs which hybridize with the genomic clone and are unique were sequenced and the DNA analyzed to determine if the sequences represent known or unique genes. All cDNA clones which appear to be unique were further analyzed as candidate BRCA1 loci. Specifically, the clones are hybridized to Northern blots to look for breast specific expression and differential expression in normal versus breast tumor RNAs. They are also analyzed by PCR on
15 clones in the BRCA1 region to verify their location. To map the extent of the locus, full length cDNAs are isolated and their sequences used as PCR probes on the YACs and the clones surrounding and including the original identifying clones. Intron-exon boundaries are then further defined through sequence analysis.

We have screened the normal breast, 8 month pregnant breast and fetal brain cDNA libraries
20 with zoo blot-positive Eco RI fragments from cosmid BAC and P1 clones in the region. Potential BRCA1 cDNA clones were identified among the three libraries. Clones were picked, replated, and screened again with the original probe to verify that they were positive.

Analysis of hybrid-selected cDNA. cDNA fragments obtained from direct selection were checked by Southern blot hybridization against the probe DNA to verify that they originated from
25 the contig. Those that passed this test were sequenced in their entirety. The set of DNA sequences obtained in this way were then checked against each other to find independent clones that overlapped. For example, the clones 694-65, 1240-1 and 1240-33 were obtained independently and subsequently shown to derive from the same contiguous cDNA sequence which has been named EST:489:1.

30 Analysis of candidate clones. One or more of the candidate genes generated from above were sequenced and the information used for identification and classification of each expressed

gene. The DNA sequences were compared to known genes by nucleotide sequence comparisons and by translation in all frames followed by a comparison with known amino acid sequences. This was accomplished using Genetic Data Environment (GDE) version 2.2 software and the Basic Local Alignment Search Tool (Blast) series of client/server software packages (e.g., BLASTN 1.3.13MP), for sequence comparison against both local and remote sequence databases (e.g., GenBank), running on Sun SPARC workstations. Sequences reconstructed from collections of cDNA clones identified with the cosmids and P1s have been generated. All candidate genes that represented new sequences were analyzed further to test their candidacy for the putative BRCA1 locus.

Mutation screening. To screen for mutations in the affected pedigrees, two different approaches were followed. First, genomic DNA isolated from family members known to carry the susceptibility allele of BRCA1 was used as a template for amplification of candidate gene sequences by PCR. If the PCR primers flank or overlap an intron/exon boundary, the amplified fragment will be larger than predicted from the cDNA sequence or will not be present in the amplified mixture. By a combination of such amplification experiments and sequencing of P1, BAC or cosmid clones using the set of designed primers it is possible to establish the intron/exon structure and ultimately obtain the DNA sequences of genomic DNA from the pedigrees.

A second approach that is much more rapid if the intron/exon structure of the candidate gene is complex involves sequencing fragments amplified from pedigree lymphocyte cDNA. cDNA synthesized from lymphocyte mRNA extracted from pedigree blood was used as a substrate for PCR amplification using the set of designed primers. If the candidate gene is expressed to a significant extent in lymphocytes, such experiments usually produce amplified fragments that can be sequenced directly without knowledge of intron/exon junctions.

The products of such sequencing reactions were analyzed by gel electrophoresis to determine positions in the sequence that contain either mutations such as deletions or insertions, or base pair substitutions that cause amino acid changes or other detrimental effects.

Any sequence within the BRCA1 region that is expressed in breast is considered to be a candidate gene for BRCA1. Compelling evidence that a given candidate gene corresponds to BRCA1 comes from a demonstration that pedigree families contain defective alleles of the candidate.

EXAMPLE 8**Identification of BRCA1**

Identification of BRCA1. Using several strategies, a detailed map of transcripts was developed for the 600 kb region of 17q21 between D17S1321 and D17S1324. Candidate expressed sequences were defined as DNA sequences obtained from: 1) direct screening of breast, fetal brain, or lymphocyte cDNA libraries, 2) hybrid selection of breast, lymphocyte or ovary cDNAs, or 3) random sequencing of genomic DNA and prediction of coding exons by XPOUND (Thomas and Skolnick, 1994). These expressed sequences in many cases were assembled into contigs composed of several independently identified sequences. Candidate genes may comprise more than one of these candidate expressed sequences. Sixty-five candidate expressed sequences within this region were identified by hybrid selection, by direct screening of cDNA libraries, and by random sequencing of P1 subclones. Expressed sequences were characterized by transcript size, DNA sequence, database comparison, expression pattern, genomic structure, and, most importantly, DNA sequence analysis in individuals from kindreds segregating 17q-linked breast and ovarian cancer susceptibility.

Three independent contigs of expressed sequence, 1141:1 (649 bp), 694:5 (213 bp) and 754:2 (1079 bp) were isolated and eventually shown to represent portions of BRCA1. When ESTs for these contigs were used as hybridization probes for Northern analysis, a single transcript of approximately 7.8 kb was observed in normal breast mRNA, suggesting that they encode different portions of a single gene. Screens of breast, fetal brain, thymus, testes, lymphocyte and placental cDNA libraries and PCR experiments with breast mRNA linked the 1141:1, 694:5 and 754:2 contigs. 5' RACE experiments with thymus, testes, and breast mRNA extended the contig to the putative 5' end, yielding a composite full length sequence. PCR and direct sequencing of P1s and BACs in the region were used to identify the location of introns and allowed the determination of splice donor and acceptor sites. These three expressed sequences were merged into a single transcription unit that proved in the final analysis to be BRCA1. This transcription unit is located adjacent to D17S855 in the center of the 600 kb region (Fig. 4).

Combination of sequences obtained from cDNA clones, hybrid selection sequences, and amplified PCR products allowed construction of a composite full length BRCA1 cDNA (SEQ ID NO:1). The sequence of the BRCA1 cDNA (up through the stop codon) has also been deposited

with GenBank and assigned accession number U-14680. This deposited sequence is incorporated herein by reference. The cDNA clone extending farthest in the 3' direction contains a poly(A) tract preceded by a polyadenylation signal. Conceptual translation of the cDNA revealed a single long open reading frame of 208 kilodaltons (amino acid sequence: SEQ ID NO:2) with a potential initiation codon flanked by sequences resembling the Kozak consensus sequence (Kozak, 1987).
5 Smith-Waterman (Smith and Waterman, 1981) and BLAST (Altschul *et al.*, 1990) searches identified a sequence near the amino terminus with considerable homology to zinc-finger domains (Fig. 5). This sequence contains cysteine and histidine residues present in the consensus C3HC4 zinc-finger motif and shares multiple other residues with zinc-finger proteins in the databases. The
10 BRCA1 gene is composed of 23 coding exons arrayed over more than 100 kb of genomic DNA (Fig. 6). Northern blots using fragments of the BRCA1 cDNA as probes identified a single transcript of about 7.8 kb, present most abundantly in breast, thymus and testis, and also present in ovary (Fig. 7). Four alternatively spliced products were observed as independent cDNA clones; 3 of these were detected in breast and 2 in ovary mRNA (Fig. 6). A PCR survey from tissue cDNAs
15 further supports the idea that there is considerable heterogeneity near the 5' end of transcripts from this gene; the molecular basis for the heterogeneity involves differential choice of the first splice donor site, and the changes detected all alter the transcript in the region 5' of the identified start codon. We have detected six potential alternate splice donors in this 5' untranslated region, with the longest deletion being 1,155 bp. The predominant form of the BRCA1 protein in breast and
20 ovary lacks exon 4. The nucleotide sequence for BRCA1 exon 4 is shown in SEQ ID NO:11, with the predicted amino acid sequence shown in SEQ ID NO:12.

Additional 5' sequence of BRCA1 genomic DNA is set forth in SEQ ID NO:13. The G at position 1 represents the potential start site in testis. The A in position 140 represents the potential start site in somatic tissue. There are six alternative splice forms of this 5' sequence as shown in
25 Figure 8. The G at position 356 represents the canonical first splice donor site. The G at position 444 represents the first splice donor site in two clones (testis 1 and testis 2). The G at position 889 represents the first splice donor site in thymus 3. A fourth splice donor site is the G at position 1230. The T at position 1513 represents the splice acceptor site for all of the above splice donors. A fifth alternate splice form has a first splice donor site at position 349 with a first acceptor site at
30 position 591 and a second splice donor site at position 889 and a second acceptor site at position 1513. A sixth alternate form is unspliced in this 5' region. The A at position 1532 is the canonical

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start site, which appears at position 120 of SEQ ID NO:1. Partial genomic DNA sequences determined for BRCA1 are set forth in Figures 10A-10H and SEQ ID Numbers:14-34. The lower case letters (in figures 10A-10H) denote intron sequence while the upper case letters denote exon sequence. Indefinite intervals within introns are designated with vvvvvvvvvvvv in Figures 10A-
5 10H. The intron/exon junctions are shown in Table 9. The CAG found at the 5' end of exons 8 and 14 is found in some cDNAs but not in others. Known polymorphic sites are shown in Figures 10A-10H in boldface type and are underlined. The known polymorphisms are listed in Tables 18 and 19.

TABLE 2

Exon No.	Base Position		Length	Intron Borders	
	5'	3'		5'	3'
e1	1	100	100	GATAAAATTAAAACTGCGACTGCGGGCGTG ³⁵	GTAGTAGAGTCCCGGAAAAGGACAGGGG ³⁶
e2	101	199	99	ATATATATATAGTTTTTCTAATGTGTTAAAG ³⁷	GTAAGTCAGCACACAAGAGTGTATTAATTTGG ³⁸
e3	200	253	54	TTTCTTTTCTCCCGCCCTACCCCTGCTAG ³⁹	GTAAGTTTGAATGTGTTATGTGGCTCCATT ⁴⁰
e4	***	***	111	AGCTACTTTTTTTTTTTTTTTTGTGACAG ⁴¹	GTAAGTGCACACCACCATATCCAGCTAAAT ⁴²
e5	254	331	78	AATTGTTCTTTCTTTCTTTTATATAATTATAG ⁴³	GTATATAAATTTGGTAATGATGCTAGGTTGG ⁴⁴
e6	332	420	89	GAGTGTGTTTCTCAAAACAATTAAATTTTCAG ⁴⁵	GTAAGTGTGTAATATCCCAAGAATGACACT ⁴⁶
e7	421	560	140	AAACATAATGTTTTCCCTGTATTTTACAG ⁴⁷	GTAAACCATTGTTTTTCTTCTTCTTCTTC ⁴⁸
e8	561	666	106	TGCTTGACTGTCTTTTACCATACTGTTTAG ⁴⁹	GTAAGGGTCTCAGGTTTTTTTAAAGTANTTAA ⁵⁰
e9	667	712	46	TGATTTAATTTTTTGGGGGGAATTTTTTAG ⁵¹	GTGAGTCAAAGAGAACCTTTGTCTATGAAG ⁵²
e10	713	789	77	TCTTATTAGGACTCTGTCITTTCCCTATAG ⁵³	GTAATGGCAAAAGTTTGGCCAACTTAACAGGC ⁵⁴
e11	790	4215	3426	GAGTACCCTTGTATTATTTTGTATATTTTTCAG ⁵⁵	GTATTGGAACCAGGTTTTTTGTGTTTGCCCC ⁵⁶
e12	4216	4302	87	ACATCTGAACCTCTGTTTTTTGTTATTTTAAG ⁵⁷	AGGTAAAAAGCGTGTGTGTGTGTGCACATG ⁵⁸
e13	4303	4476	174	CAITTTCTGGTACCATTATCGTTTTTTTGA ⁵⁹	GTGTGTATTGTTGGCCCAACACTGATATCT ⁶⁰
e14	4477	4603	127	AGTAGATTTGTTTTTCTCATTCATTAAAG ⁶¹	GTAAGAAACATCAATGTAAAGATGCTGTGG ⁶²

* Base numbers in SEQ ID NO:1.

** Numbers in superscript refer to SEQ ID NOS.

*** e4 from SEQ ID NO:11.

TABLE 2 (cont'd)

Exon Position*		Length	5'		Intron Borders	3'	
No.	5'		3'				
e15	4604	4794	191	ATGGTTTTCTCCTTCCATTATCTTTCTAG ^{63**}	GTAAATATTTTCATCTGCTGTATTGGAACAAA ⁶⁴		
e16	4795	5105	311	TGTAAATTAACACTTCTCCCATTCCTTTTCAG ⁶⁵	GTGAGTGTATCCATATGTATCTCCCTAATG ⁶⁶		
e17	5106	5193	88	ATGATAATGGAATATTGATTTAATTTTCAG ⁶⁷	GTATACCAAGAACCTTTACAGAAATACCTTG ⁶⁸		
e18	5194	5271	78	CTAATCCTTTGAGTGTGTTTTTCATTTCTGCAG ⁶⁹	GTAAGTATAAATACTATTCTCCCTCCTCCTCC ⁷⁰		
e19	5272	5312	41	TGTAACCTGTCTTTTCTATGATCTCTTTAG ⁷¹	GTAAGTACTTGTATGTTACAAACTAACCCAGA ⁷²		
e20	5313	5396	84	TCCTGATGGGTTGTGTTTGGTTTCTTTTCAG ⁷³	GTAAAGCTCCCTCCCTCAAGTTGACAAAAA ⁷⁴		
e21	5397	5451	55	CTGTCCCTCTCTCTTCCCTCTCTTCTTCTCCAG ⁷⁵	GTAAGAGCCTGGGAGAACCCAGAGTTCCA ⁷⁶		
e22	5452	5525	74	AGTGATTTTACATGTAAATGTCCATTTTAG ⁷⁷	GTAAGTATTGGGTGCCCTGTCTAGTGTGGGA ⁷⁸		
e23	5526	5586	61	TTGAATGCTCTTTTCTCTTCTTCTGGGATCCAG ⁷⁹	GTAAGGTGCCCTCGCATGTACCTGTGCTATT ⁸⁰		
e24	5587	5914	328	CTAATCTCTGCTTGTGTTCTCTGTCTCTCCAG ⁸¹			

* Base numbers in SEQ ID NO:1.

** Numbers in superscript refer to SEQ ID NOS.

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Low stringency blots in which genomic DNA from organisms of diverse phylogenetic background were probed with BRCA1 sequences that lack the zinc-finger region revealed strongly hybridizing fragments in human, monkey, sheep and pig, and very weak hybridization signals in rodents. This result indicates that, apart from the zinc-finger domain, BRCA1 is conserved only at a moderate level through evolution.

Germline BRCA1 mutations in 17q-linked kindreds. The most rigorous test for BRCA1 candidate genes is to search for potentially disruptive mutations in carrier individuals from kindreds that segregate 17q-linked susceptibility to breast and ovarian cancer. Such individuals must contain BRCA1 alleles that differ from the wildtype sequence. The set of DNA samples used in this analysis consisted of DNA from individuals representing 8 different BRCA1 kindreds (Table 10).

TABLE 10

KINDRED DESCRIPTIONS AND ASSOCIATED LOD SCORES

	Kindred	Cases (n)			Sporadic Cases ¹ (n)	LOD Score	Marker(s)
		Br	Br<50	Ov			
	2082	31	20	22	7	9.49	D17S1327
	2099	22	14	2*	0	2.36	D17S800/D17S855 ²
	2035	10	8	1*	0	2.25	D17S1327
	1901	10	7	1*	0	1.50	D17S855
	1925	4	3	0	0	0.55	D17S579
	1910	5	4	0	0	0.36	D17S579/D17S250 ²
	1927	5	4	0	1	-0.44	D17S250
	1911	8	5	0	2	-0.20	D17S250

¹ Number of women with breast cancer (diagnosed under age 50) or ovarian cancer (diagnosed at any age) who do not share the BRCA1-linked haplotype segregating in the remainder of the cases in the kindred.

² Multipoint LOD score calculated using both markers

* kindred contains one individual who had both breast and ovarian cancer; this individual is counted as a breast cancer case and as an ovarian cancer case.

The logarithm of the odds (LOD) scores in these kindreds range from 9.49 to -0.44 for a set of markers in 17q21. Four of the families have convincing LOD scores for linkage, and 4 have low positive or negative LOD scores. The latter kindreds were included because they demonstrate
 5 haplotype sharing at chromosome 17q21 for at least 3 affected members. Furthermore, all kindreds in the set display early age of breast cancer onset and 4 of the kindreds include at least one case of ovarian cancer, both hallmarks of BRCA1 kindreds. One kindred, 2082, has nearly equal incidence of breast and ovarian cancer, an unusual occurrence given the relative rarity of ovarian cancer in the population. All of the kindreds except two were ascertained in Utah. K2035 is from
 10 the midwest. K2099 is an African-American kindred from the southern USA.

In the initial screen for predisposing mutations in BRCA1, DNA from one individual who carries the predisposing haplotype in each kindred was tested. The 23 coding exons and associated splice junctions were amplified either from genomic DNA samples or from cDNA prepared from lymphocyte mRNA. When the amplified DNA sequences were compared to the wildtype
 15 sequence, 4 of the 8 kindred samples were found to contain sequence variants (Table 11).

TABLE 11

PREDISPOSING MUTATIONS

20

	<u>Kindred Number</u>	<u>Mutation</u>	<u>Coding Effect</u>	<u>Location*</u>
	2082	C→T	Gln→Stop	4056
25	1910	extra C	frameshift	5385
	2099	T→G	Met→Arg	5443
	2035	?	loss of transcript	
	1901	11 bp deletion	frameshift	189

30 * In Sequence ID NO:1

All four sequence variants are heterozygous and each appears in only one of the kindreds. Kindred 2082 contains a nonsense mutation in coding exon 10 (Fig. 9A), Kindred 1910 contains a
 35 single nucleotide insertion in coding exon 19 (Fig. 9B), and Kindred 2099 contains a missense mutation in coding exon 20, resulting in a Met→Arg substitution (Fig. 9C). The frameshift and

nonsense mutations are likely disruptive to the function of the BRCA1 product. The peptide encoded by the frameshift allele in Kindred 1910 would contain an altered amino acid sequence beginning 107 residues from the wildtype C-terminus. The peptide encoded by the frameshift allele in Kindred 1901 would contain an altered amino acid sequence beginning with the 24th
5 residue from the wildtype N-terminus. The mutant allele in Kindred 2082 would encode a protein missing 548 residues from the C-terminus. The missense substitution observed in Kindred 2099 is potentially disruptive as it causes the replacement of a small hydrophobic amino acid (Met), by a large charged residue (Arg). Eleven common polymorphisms were also identified, 8 in coding sequence and 3 in introns.

10 The individual studied in Kindred 2035 evidently contains a regulatory mutation in BRCA1. In her cDNA, a polymorphic site (A→G at base 3667) appeared homozygous, whereas her genomic DNA revealed heterozygosity at this position (Fig. 9C). A possible explanation for this observation is that mRNA from her mutated BRCA1 allele is absent due to a mutation that affects its production or stability. This possibility was explored further by examining 5 polymorphic sites
15 in the BRCA1 coding region, which are separated by as much as 3.5 kb in the BRCA1 transcript. In all cases where her genomic DNA appeared heterozygous for a polymorphism, cDNA appeared homozygous. In individuals from other kindreds and in non-haplotype carriers in Kindred 2035, these polymorphic sites could be observed as heterozygous in cDNA, implying that amplification from cDNA was not biased in favor of one allele. This analysis indicates that a BRCA1 mutation
20 in Kindred 2035 either prevents transcription or causes instability or aberrant splicing of the BRCA1 transcript.

Cosegregation of BRCA1 mutations with BRCA1 haplotypes and population frequency analysis. In addition to potentially disrupting protein function, two criteria must be met for a
25 sequence variant to qualify as a candidate predisposing mutation. The variant must: 1) be present in individuals from the kindred who carry the predisposing BRCA1 haplotype and absent in other members of the kindred, and 2) be rare in the general population.

Each mutation was tested for cosegregation with BRCA1. For the frameshift mutation in Kindred 1910, two other haplotype carriers and one non-carrier were sequenced (Fig. 9B). Only
30 the carriers exhibited the frameshift mutation. The C to T change in Kindred 2082 created a new AvrII restriction site. Other carriers and non-carriers in the kindred were tested for the presence of

the restriction site (Fig. 9A). An allele-specific oligonucleotide (ASO) was designed to detect the presence of the sequence variant in Kindred 2099. Several individuals from the kindred, some known to carry the haplotype associated with the predisposing allele, and others known not to carry the associated haplotype, were screened by ASO for the mutation previously detected in the kindred. In each kindred, the corresponding mutant allele was detected in individuals carrying the BRCA1-associated haplotype, and was not detected in noncarriers. In the case of the potential regulatory mutation observed in the individual from Kindred 2035, cDNA and genomic DNA from carriers in the kindred were compared for heterozygosity at polymorphic sites. In every instance, the extinguished allele in the cDNA sample was shown to lie on the chromosome that carries the BRCA1 predisposing allele (Fig. 9C).

To exclude the possibility that the mutations were simply common polymorphisms in the population, ASOs for each mutation were used to screen a set of normal DNA samples. Gene frequency estimates in Caucasians were based on random samples from the Utah population. Gene frequency estimates in African-Americans were based on 39 samples provided by M. Peracek-Vance which originate from African-Americans used in her linkage studies and 20 newborn Utah African-Americans. None of the 4 potential predisposing mutations was found in the appropriate control population, indicating that they are rare in the general population. Thus, two important requirements for BRCA1 susceptibility alleles were fulfilled by the candidate predisposing mutations: 1) cosegregation of the mutant allele with disease, and 2) absence of the mutant allele in controls, indicating a low gene frequency in the general population.

Phenotypic Expression of BRCA1 Mutations. The effect of the mutations on the BRCA1 protein correlated with differences in the observed phenotypic expression in the BRCA1 kindreds. Most BRCA1 kindreds have a moderately increased ovarian cancer risk, and a smaller subset have high risks of ovarian cancer, comparable to those for breast cancer (Easton *et al.*, 1993). Three of the four kindreds in which BRCA1 mutations were detected fall into the former category, while the fourth (K2082) falls into the high ovarian cancer risk group. Since the BRCA1 nonsense mutation found in K2082 lies closer to the amino terminus than the other mutations detected, it might be expected to have a different phenotype. In fact, Kindred K2082 mutation has a high incidence of ovarian cancer, and a later mean age at diagnosis of breast cancer cases than the other kindreds (Goldgar *et al.*, 1994). This difference in age of onset could be due to an ascertainment bias in the

smaller, more highly penetrant families, or it could reflect tissue-specific differences in the behavior of BRCA1 mutations. The other 3 kindreds that segregate known BRCA1 mutations have, on average, one ovarian cancer for every 10 cases of breast cancer, but have a high proportion of breast cancer cases diagnosed in their late 20's or early 30's. Kindred 1910, which has a frameshift mutation, is noteworthy because three of the four affected individuals had bilateral breast cancer, and in each case the second tumor was diagnosed within a year of the first occurrence. Kindred 2035, which segregates a potential regulatory BRCA1 mutation, might also be expected to have a dramatic phenotype. Eighty percent of breast cancer cases in this kindred occur under age 50. This figure is as high as any in the set, suggesting a BRCA1 mutant allele of high penetrance (Table 10).

Although the mutations described above clearly are deleterious, causing breast cancer in women at very young ages, each of the four kindreds with mutations includes at least one woman who carries the mutation who lived until age 80 without developing a malignancy. It will be of utmost importance in the studies that follow to identify other genetic or environmental factors that may ameliorate the effects of BRCA1 mutations.

In four of the eight putative BRCA1-linked kindreds, potential predisposing mutations were not found. Three of these four have LOD scores for BRCA1-linked markers of less than 0.55. Thus, these kindreds may not in reality segregate BRCA1 predisposing alleles. Alternatively, the mutations in these four kindreds may lie in regions of BRCA1 that, for example, affect the level of transcript and therefore have thus far escaped detection.

Role of BRCA1 in Cancer. Most tumor suppressor genes identified to date give rise to protein products that are absent, nonfunctional, or reduced in function. The majority of TP53 mutations are missense; some of these have been shown to produce abnormal p53 molecules that interfere with the function of the wildtype product (Shaulian *et al.* 1992; Srivastava *et al.*, 1993). A similar dominant negative mechanism of action has been proposed for some adenomatous polyposis coli (APC) alleles that produce truncated molecules (Su *et al.*, 1993), and for point mutations in the Wilms' tumor gene (WT1) that alter DNA binding of the protein (Little *et al.*, 1993). The nature of the mutations observed in the BRCA1 coding sequence is consistent with production of either dominant negative proteins or nonfunctional proteins. The regulatory

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mutation inferred in Kindred 2035 cannot be a dominant negative; rather, this mutation likely causes reduction or complete loss of BRCA1 expression from the affected allele.

The BRCA1 protein contains a C₃HC₄ zinc-finger domain, similar to those found in numerous DNA binding proteins and implicated in zinc-dependent binding to nucleic acids. The first 180 amino acids of BRCA1 contain five more basic residues than acidic residues. In contrast, the remainder of the molecule is very acidic, with a net excess of 70 acidic residues. The excess negative charge is particularly concentrated near the C-terminus. Thus, one possibility is that BRCA1 encodes a transcription factor with an N-terminal DNA binding domain and a C-terminal transactivational "acidic blob" domain. Interestingly, another familial tumor suppressor gene, WT1, also contains a zinc-finger motif (Haber *et al.*, 1990). Many cancer predisposing mutations in WT1 alter zinc-finger domains (Little *et al.*, 1993; Haber *et al.*, 1990; Little *et al.*, 1992). WT1 encodes a transcription factor, and alternative splicing of exons that encode parts of the zinc-finger domain alter the DNA binding properties of WT1 (Bickmore *et al.*, 1992). Some alternatively spliced forms of WT1 mRNA generate molecules that act as transcriptional repressors (Drummond *et al.*, 1994). Some BRCA1 splicing variants may alter the zinc-finger motif, raising the possibility that a regulatory mechanism similar to that which occurs in WT1 may apply to BRCA1.

EXAMPLE 9

Analysis of Tumors for BRCA1 Mutations

To focus the analysis on tumors most likely to contain BRCA1 mutations, primary breast and ovarian carcinomas were typed for LOH in the BRCA1 region. Three highly polymorphic, simple tandem repeat markers were used to assess LOH: D17S1323 and D17S855, which are intragenic to BRCA1, and D17S1327, which lies approximately 100 kb distal to BRCA1. The combined LOH frequency in informative cases (i.e., where the germline was heterozygous) was 32/72 (44%) for the breast carcinomas and 12/21 (57%) for the ovarian carcinomas, consistent with previous measurements of LOH in the region (Futreal *et al.*, 1992b; Jacobs *et al.*, 1993; Sato *et al.*, 1990; Eccles *et al.*, 1990; Cropp *et al.*, 1994). The analysis thus defined a panel of 32 breast tumors and 12 ovarian tumors of mixed race and age of onset to be examined for BRCA mutations.

The complete 5,589 bp coding region and intron/exon boundary sequences of the gene were

screened in this tumor set by direct sequencing alone or by a combination of single-strand conformation analysis (SSCA) and direct sequencing.

A total of six mutations was found, one in an ovarian tumor, four in breast tumors and one in a male unaffected haplotype carrier (Table 12). One mutation, Glu1541Ter, introduced a stop codon that would create a truncated protein missing 273 amino acids at the carboxy terminus. In addition, two missense mutations were identified. These are Ala1708Glu and Met1775Arg and involve substitutions of small, hydrophobic residues by charged residues. Patients 17764 and 19964 are from the same family. In patient OV24 nucleotide 2575 is deleted and in patients 17764 and 19964 nucleotides 2993-2996 are deleted.

TABLE 12

Predisposing Mutations

	<u>Patient</u>	<u>Codon</u>	<u>Nucleotide Change</u>	<u>Amino Acid Change</u>	<u>Age of Onset</u>	<u>Family History</u>
	BT098	1541	GAG → TAG	Glu → Stop	39	-
	OV24	819	1 bp deletion	frameshift	44	-
	BT106	1708	GCG → GAG	Ala → Glu	24	+
	MC44	1775	ATG → AGG	Met → Arg	42	+
	17764	958	4 bp deletion	frameshift	31	+
	19964	958	4 bp deletion	frameshift		++

* Unaffected haplotype carrier, male

Several lines of evidence suggest that all five mutations represent BRCA1 susceptibility alleles:

- (i) all mutations are present in the germline;
- (ii) all are absent in appropriate control populations, suggesting they are not common polymorphisms;
- (iii) each mutant allele is retained in the tumor, as is the case in tumors from patients belonging to kindreds that segregate BRCA1 susceptibility alleles (Smith *et al.*, 1992; Kelsell *et*

al., 1993) (if the mutations represented neutral polymorphisms, they should be retained in only 50% of the cases);

(iv) the age of onset in the four breast cancer cases with mutations varied between 24 and 42 years of age, consistent with the early age of onset of breast cancer in individuals with BRCA1 susceptibility; similarly, the ovarian cancer case was diagnosed at 44, an age that falls in the youngest 13% of all ovarian cancer cases; and finally,

(v) three of the five cases have positive family histories of breast or ovarian cancer found retrospectively in their medical records, although the tumor set was not selected with regard to this criterion.

BT106 was diagnosed at age 24 with breast cancer. Her mother had ovarian cancer, her father had melanoma, and her paternal grandmother also had breast cancer. Patient MC44, an African-American, had bilateral breast cancer at age 42. This patient had a sister who died of breast cancer at age 34, another sister who died of lymphoma, and a brother who died of lung cancer. Her mutation (Met1775Arg) had been detected previously in Kindred 2099, an African-American family that segregates a BRCA1 susceptibility allele, and was absent in African-American and Caucasian controls. Patient MC44, to our knowledge, is unrelated to Kindred 2099. The detection of a rare mutant allele, once in a BRCA1 kindred and once in the germline of an apparently unrelated early-onset breast cancer case, suggests that the Met1775Arg change may be a common predisposing mutation in African-Americans. Collectively, these observations indicate that all four BRCA1 mutations in tumors represent susceptibility alleles; no somatic mutations were detected in the samples analyzed.

The paucity of somatic BRCA1 mutations is unexpected, given the frequency of LOH on 17q, and the usual role of susceptibility genes as tumor suppressors in cancer progression. There are three possible explanations for this result: (i) some BRCA1 mutations in coding sequences were missed by our screening procedure; (ii) BRCA1 somatic mutations fall primarily outside the coding exons; and (iii) LOH events in 17q do not reflect BRCA1 somatic mutations.

If somatic BRCA1 mutations truly are rare in breast and ovary carcinomas, this would have strong implications for the biology of BRCA1. The apparent lack of somatic BRCA1 mutations implies that there may be some fundamental difference in the genesis of tumors in genetically predisposed BRCA1 carriers, compared with tumors in the general population. For example, mutations in BRCA1 may have an effect only on tumor formation at a specific stage early in breast

and ovarian development. This possibility is consistent with a primary function for BRCA1 in premenopausal breast cancer. Such a model for the role of BRCA1 in breast and ovarian cancer predicts an interaction between reproductive hormones and BRCA1 function. However, no clinical or pathological differences in familial versus sporadic breast and ovary tumors, other than age of onset, have been described (Lynch *et al.*, 1990). On the other hand, the recent finding of increased TP53 mutation and microsatellite instability in breast tumors from patients with a family history of breast cancer (Glebov *et al.*, 1994) may reflect some difference in tumors that arise in genetically predisposed persons. The involvement of BRCA1 in this phenomenon can now be addressed directly. Alternatively, the lack of somatic BRCA1 mutations may result from the existence of multiple genes that function in the same pathway of tumor suppression as BRCA1, but which collectively represent a more favored target for mutation in sporadic tumors. Since mutation of a single element in a genetic pathway is generally sufficient to disrupt the pathway, BRCA1 might mutate at a rate that is far lower than the sum of the mutational rates of the other elements.

A separate study to analyze tumors for BRCA1 mutations was performed in Japan. A panel of 103 patients representing early-onset cases (<35 years of age) (46 patients), members of multiply-affected families (12 patients), and/or had developed bilateral breast cancers (59 patients) were screened for mutations in BRCA1. Primary breast tumors from these patients were screened for mutations in coding exons of BRCA1 using single-strand conformation polymorphism (SSCP) analysis. For exon 11, which is 3425 bp long, PCR primers were designed to amplify eleven overlapping segments of this exon separately. Each of the other 22 exons was amplified individually in a single PCR. Thus 33 PCR-SSCP analyses were carried out for each case. Mutations were detected in tumors from four patients, all of whom had developed breast cancers bilaterally (Table 12A). One mutation resulted in a frame shift due to a 2 bp deletion (deletion of AA) at codon 797. This gives rise to a truncated protein missing 1065 amino acids at the COOH terminus. A second mutation was a nonsense mutation at codon 1214 due to a G → T transversion of the first nucleotide of the codon. This results in a premature stop codon in place of glutamic acid at this site and results in a truncated protein missing 649 amino acids at the COOH terminus. There were also two missense mutations. One was a G → A transition at the first nucleotide of codon 271 resulting in a Val → Met substitution. The second was at codon 1150 (a C → T transition in the first nucleotide of the codon) causing a Pro → Ser substitution, a replacement of a hydrophobic nonpolar amino acid with a polar uncharged amino acid. These mutations were all

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found to be germline mutations. The mean age of onset in these four patients was 49. These studies also found a common neutral polymorphism of either C or T at the first nucleotide of codon 771.

5

TABLE 12A**Predisposing Mutations**

	<u>Patient</u>	<u>Codon</u>	<u>Nucleotide Change</u>	<u>Amino Acid Change</u>	<u>Age of Onset</u>
10	23	1150	CCT→TCT	Pro→Ser	49 & 64
	44	1214	GAG→TAG	Glu→Stop	51 & 51
	98	271	GTG→ATG	Val→Met	45 & 45
	100	797	2bp deletion	frameshift	50 & 71
	5	482-483	4bp deletion	frameshift	45
15	6	856	TAT→CAT	Tyr→His	54
	7	271	GTG→ATG	Val→Met	49 & 49
	8	852	1bp deletion	frameshift	62

Although patients 98 and 7 show the same mutation, they are not related to each other.

20

EXAMPLE 10**Analysis of the BRCA1 Gene**

The structure and function of BRCA 1 gene are determined according to the following methods.

25

Biological Studies. Mammalian expression vectors containing BRCA1 cDNA are constructed and transfected into appropriate breast carcinoma cells with lesions in the gene. Wild-type BRCA1 cDNA as well as altered BRCA1 cDNA are utilized. The altered BRCA1 cDNA can be obtained from altered BRCA1 alleles or produced as described below. Phenotypic reversion in cultures (e.g., cell morphology, doubling time, anchorage-independent growth) and in animals

30

(e.g., tumorigenicity) is examined. The studies will employ both wild-type and mutant forms (Section B) of the gene.

Molecular Genetics Studies. *In vitro* mutagenesis is performed to construct deletion mutants and missense mutants (by single base-pair substitutions in individual codons and cluster charged
5 → alanine scanning mutagenesis). The mutants are used in biological, biochemical and biophysical studies.

Mechanism Studies. The ability of BRCA1 protein to bind to known and unknown DNA sequences is examined. Its ability to transactivate promoters is analyzed by transient reporter expression systems in mammalian cells. Conventional procedures such as particle-capture and
10 yeast two-hybrid system are used to discover and identify any functional partners. The nature and functions of the partners are characterized. These partners in turn are targets for drug discovery.

Structural Studies. Recombinant proteins are produced in *E. coli*, yeast, insect and/or mammalian cells and are used in crystallographical and NMR studies. Molecular modeling of the proteins is also employed. These studies facilitate structure-driven drug design.

EXAMPLE 11

Two Step Assay to Detect the Presence of BRCA1 in a Sample

Patient sample is processed according to the method disclosed by Antonarakis, *et al.* (1985),
20 separated through a 1% agarose gel and transferred to nylon membrane for Southern blot analysis. Membranes are UV cross linked at 150 mJ using a GS Gene Linker (Bio-Rad). BRCA1 probe corresponding to nucleotide positions 3631-3930 of SEQ ID NO:1 is subcloned into pTZ18U. The phagemids are transformed into *E. coli* MV1190 infected with M13KO7 helper phage (Bio-Rad, Richmond, CA). Single stranded DNA is isolated according to standard procedures (see
25 Sambrook, *et al.*, 1989).

Blots are prehybridized for 15-30 min at 65°C in 7% sodium dodecyl sulfate (SDS) in 0.5 M NaPO₄. The methods follow those described by Nguyen, *et al.*, 1992. The blots are hybridized overnight at 65°C in 7% SDS, 0.5 M NaPO₄ with 25-50 ng/ml single stranded probe DNA. Post-hybridization washes consist of two 30 min washes in 5% SDS, 40 mM NaPO₄ at 65°C, followed
30 by two 30-min washes in 1% SDS, 40 mM NaPO₄ at 65°C.

Next the blots are rinsed with phosphate buffered saline (pH 6.8) for 5 min at room temperature and incubated with 0.2% casein in PBS for 30-60 min at room temperature and rinsed in PBS for 5 min. The blots are then preincubated for 5-10 minutes in a shaking water bath at 45°C with hybridization buffer consisting of 6 M urea, 0.3 M NaCl, and 5X Denhardt's solution (see Sambrook, *et al.*, 1989). The buffer is removed and replaced with 50-75 $\mu\text{l}/\text{cm}^2$ fresh hybridization buffer plus 2.5 nM of the covalently cross-linked oligonucleotide-alkaline phosphatase conjugate with the nucleotide sequence complementary to the universal primer site (UP-AP, Bio-Rad). The blots are hybridized for 20-30 min at 45°C and post hybridization washes are incubated at 45°C as two 10 min washes in 6 M urea, 1x standard saline citrate (SSC), 0.1% SDS and one 10 min wash in 1x SSC, 0.1% Triton[®]X-100. The blots are rinsed for 10 min at room temperature with 1x SSC.

Blots are incubated for 10 min at room temperature with shaking in the substrate buffer consisting of 0.1 M diethanolamine, 1 mM MgCl_2 , 0.02% sodium azide, pH 10.0. Individual blots are placed in heat sealable bags with substrate buffer and 0.2 mM AMPPD (3-(2'-spiroadamantane)-4-methoxy-4-(3'-phosphoryloxy)phenyl-1,2-dioxetane, disodium salt, Bio-Rad).

After a 20 min incubation at room temperature with shaking, the excess AMPPD solution is removed. The blot is exposed to X-ray film overnight. Positive bands indicate the presence of BRCA1.

EXAMPLE 12

Generation of Polyclonal Antibody against BRCA1

Segments of BRCA1 coding sequence were expressed as fusion protein in *E. coli*. The overexpressed protein was purified by gel elution and used to immunize rabbits and mice using a procedure similar to the one described by Harlow and Lane, 1988. This procedure has been shown to generate Abs against various other proteins (for example, see Kraemer, *et al.*, 1993).

Briefly, a stretch of BRCA1 coding sequence was cloned as a fusion protein in plasmid PET5A (Novagen, Inc., Madison, WI). The BRCA1 incorporated sequence includes the amino acids corresponding to #1361-1554 of SEQ ID NO:2. After induction with IPTG, the overexpression of a fusion protein with the expected molecular weight was verified by SDS/PAGE. Fusion protein was purified from the gel by electroelution. The identification of the protein as the

BRCA1 fusion product was verified by protein sequencing at the N-terminus. Next, the purified protein was used as immunogen in rabbits. Rabbits were immunized with 100 µg of the protein in complete Freund's adjuvant and boosted twice in 3 week intervals, first with 100 µg of immunogen in incomplete Freund's adjuvant followed by 100 µg of immunogen in PBS. Antibody containing serum is collected two weeks thereafter.

This procedure is repeated to generate antibodies against the mutant forms of the BRCA1 gene. These antibodies, in conjunction with antibodies to wild type BRCA1, are used to detect the presence and the relative level of the mutant forms in various tissues and biological fluids.

EXAMPLE 13

Generation of Monoclonal Antibodies Specific for BRCA1

Monoclonal antibodies are generated according to the following protocol. Mice are immunized with immunogen comprising intact BRCA1 or BRCA1 peptides (wild type or mutant) conjugated to keyhole limpet hemocyanin using glutaraldehyde or EDC as is well known.

The immunogen is mixed with an adjuvant. Each mouse receives four injections of 10 to 100 µg of immunogen and after the fourth injection blood samples are taken from the mice to determine if the serum contains antibody to the immunogen. Serum titer is determined by ELISA or RIA. Mice with sera indicating the presence of antibody to the immunogen are selected for hybridoma production.

Spleens are removed from immune mice and a single cell suspension is prepared (see Harlow and Lane, 1988). Cell fusions are performed essentially as described by Kohler and Milstein, 1975. Briefly, P3.65.3 myeloma cells (American Type Culture Collection, Rockville, MD) are fused with immune spleen cells using polyethylene glycol as described by Harlow and Lane, 1988.

Cells are plated at a density of 2×10^5 cells/well in 96 well tissue culture plates. Individual wells are examined for growth and the supernatants of wells with growth are tested for the presence of BRCA1 specific antibodies by ELISA or RIA using wild type or mutant BRCA1 target protein. Cells in positive wells are expanded and subcloned to establish and confirm monoclonality.

Clones with the desired specificities are expanded and grown as ascites in mice or in a hollow fiber system to produce sufficient quantities of antibody for characterization and assay development.

EXAMPLE 14**Sandwich Assay for BRCA1**

5 Monoclonal antibody is attached to a solid surface such as a plate, tube, bead, or particle. Preferably, the antibody is attached to the well surface of a 96-well ELISA plate. 100 μ l sample (e.g., serum, urine, tissue cytosol) containing the BRCA1 peptide/protein (wild-type or mutant) is added to the solid phase antibody. The sample is incubated for 2 hrs at room temperature. Next the sample fluid is decanted, and the solid phase is washed with buffer to remove unbound
10 material. 100 μ l of a second monoclonal antibody (to a different determinant on the BRCA1 peptide/protein) is added to the solid phase. This antibody is labeled with a detector molecule (e.g., 125-I, enzyme, fluorophore, or a chromophore) and the solid phase with the second antibody is incubated for two hrs at room temperature. The second antibody is decanted and the solid phase is washed with buffer to remove unbound material.

15 The amount of bound label, which is proportional to the amount of BRCA1 peptide/protein present in the sample, is quantitated. Separate assays are performed using monoclonal antibodies which are specific for the wild-type BRCA1 as well as monoclonal antibodies specific for each of the mutations identified in BRCA1.

EXAMPLE 15**Analysis of BRCA1 Mutations**

20 The DNA samples which were screened for BRCA1 mutations were extracted from blood or tumor samples from patients with breast or ovarian cancer (or known carriers by haplotype analysis) who were participating in research studies on the genetics of breast cancer. All subjects
25 signed appropriate informed consent. Table 13 details the number of samples, ascertainment criteria, and screening method for each set of samples screened.

TABLE 13
Sets of DNA Samples Screened for Mutations in BRCA1

Source of Samples	Description of Samples ¹	Screening Method ²	No. Samples Screened	No. Mutations Found to Date
UTAH-2	Br/Ov Families	SEQ	10	2
MONTREAL	Br/Ov Families	SEQ	30	13
MSKCC-1	Br and Br/Ov Families	SEQ	14	2
MSK/UT-1	Early Onset Br Cases	SEQ	24	1
STRANG	Br and Br/Ov Families	SEQ	12	4
STOCKHOLM	Br and Br/Ov Families	SEQ	15	4
USC-1	Bilat Br Proband, High-Risk	SEQ	7	3
TUMOR-3	Early Onset Br Tumors	SEQ	14	1
USC-2	Bilat Br<50 + 1° rel Br	ASO	59	5
MSK/UT-2	Early Onset Br Cases	ASO	109	3
YN	Bilateral; Early Onset	SSCA	103	4
Texas	Br/Ov Families	SEQ	15	2
Utah	Br/Ov Families	SEQ	10	1
Pisa	Br/Ov Families	SEQ	21	4

TABLE 13 (cont'd)

Tumor/mod	SEQ	1
MSKCC-2	Early Onset Br Cases	21
		3

1 Most sample groups contained a heterogeneous mixture of samples. The most representative description of each set is given.

2 SEQ - Direct sequencing of PCR products; SSCA - Single Strand Conformation Assay; ASO - Allele-Specific Oligo

Although the original mutations described in Miki *et al.*, 1994 were detected through screening of cDNA, 25 pairs of intronic PCR primers were used to amplify the complete coding sequence and splice junctions from genomic DNA for the majority of the remaining samples. Updated primer information is publicly available via anonymous ftp from morgan.med.utah.edu in the directory pub/BRCA1. Where possible, DNA sequence variations were tested for cosegregation with breast or ovarian cancer in the family. Further evidence of a causal role of a sequence variant in cancer was provided by proving the absence of the putative mutation in a set of control individuals. Screening for specific, previously-identified mutations in large sets of selected samples was performed using ASO hybridization.

Table 14 describes many of the mutations found screening the entire BRCA1 coding sequence as well as the intron/exon boundaries and by finding polymorphic sites in genomic DNA reduced to monomorphic sites in cDNA. Two common mutations were found and their frequencies in other samples were examined by ASO analysis (Table 15). Tables 16 and 17 describe the distribution of mutations by type and by location within the BRCA1 coding sequence, respectively. By far, the majority of mutations identified were frameshifts. Globally, no statistically significant departure from a random distribution across the coding sequence of BRCA1 was found ($\chi^2 = 2.00$, 2 df, $p = 0.37$) among the distinct mutations found in the coding sequence of BRCA1 to date.

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TABLE 14
Mutations Identified by Complete Screening of the BRCA1 Gene

Sample Set	Family	# Cases BR QV	Type ¹	Exon	Mutation Description Mutation ²
TEXAS	132-000				
MONTREAL	180	2	FS	2	185 ins A -> ter 40
MONTREAL	235	2	FS	2	185 del AG -> ter 39
MONTREAL	253	4	FS	2	185 del AG -> ter 39
MONTREAL	255	1	FS	2	185 del AG -> ter 39
MONTREAL	255	0	FS	2	185 del AG -> ter 39
MSKCC	210311	3	FS	2	185 del AG -> ter 39
USC-1	008	2	FS	2	185 del AG -> ter 39
PISA	27	8	MS	5	Cys 64 Arg
UTAH			SP	I-5	T->G ins 59 -> ter 75
MSKCC	19921		SP	I-6	del A at -2 of 3' splice
TUMOR-3 ⁴	-	1	FS	11	926 ins 10 -> ter 289
MSK/UT-1	-	1	FS	11	926 ins 10 -> ter 289
YN98	-	1	MS	11	Val 271 Met
YN7	-	1	MS	11	Val 271 Met
MONTREAL	270	4	FS	11	1128 ins A -> ter 345
STRANG	2903	1	FS	11	1128 ins A -> ter 345
MONTREAL	185	1	FS	11	1294 del 40 -> ter 396
PISA	6		FS	11	1499 ins A -> ter 479
PISA	17		FS	11	1499 ins A -> ter 479
PISA	31		FS	11	1499 ins A -> ter 479
YN5	-	1	FS	11	del 4 -> ter

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TABLE 14 (Cont'd)
Mutations Identified by Complete Screening of the BRCA1 Gene

Sample Set	Family	# Cases		Type ¹	Mutation Description	
		BR	OV		Exon	Mutation ²
USC-1	052	5	1	FS	11	655 2080 ins A -> ter 672
USC-1	068	2	1	FS	11	655 2080 ins A -> ter 672
PISA				MS	11	667 Gln 667 His
STRANG	2802	2	2	FS	11	725 2293 del G -> ter 735
YN100	-	1	0	FS	11	797 2509 del AA -> ter 799
TUMOR1mod	OV24	0	1	FS	11	819 2575 del C -> ter 845
MONTREAL	179	2	3	MS	11	826 Thr 826 Lys
STOCKHOLM	AL48	3	1	FS	11	826 2596 del C -> ter 845
STOCKHOLM	BR33	5	1	FS	11	826 2596 del C -> ter 845
YN8		1	0	FS	11	852 del 1 -> ter 891
YN6		1	0	MS	11	856 Tyr 856 His
UTAH-2	2305	2	7	FS	11	958 2993 del 4 -> ter 998
MONTREAL	218	5	1	FS	11	1002 3121 del A -> ter 1023
MSK17572				MS	11	1008 Met 1008 Ile
STOCKHOLM	BR24	2	1	FS	11	1016 3166 ins 5 -> ter 1025
MONTREAL				FS	11	1110 3447 del 4 -> ter 1115
MONTREAL	448			FS	11	1110 3449 del 4 -> ter 1115
TEXAS	BC110-001			FS	11	1111 3450 del 4 -> ter 1115
YN23	-	1	0	MS	11	1150 Pro 1150 Ser
STOCKHOLM	PAL33	1	0	FS	11	1209 3745 del T -> ter 1209
YN44	-	1	0	NS	11	1214 Glu 1214 ter

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TABLE 14 (Cont'd)
Mutations Identified by Complete Screening of the BRCA1 Gene

Sample Set	Family	# Cases BR QV	Type ¹	Exon	Codon	Mutation Description	Mutation ²
MSK12871			MS	11	1219	Glu 1219 Asp	
TEXAS	BC215-000		FS	11	1252	3873 del 4 ->	ter 1262
UTAH-2	2039	3 2	MS	11	1347	Arg 1347 Gly	
MONTREAL	183	4 1	FS	11	1355	4184 del 4 ->	ter 1364
STRANG	1900 ³	3 1	NS	13	1443	Arg 1443 ter	
TUMOR-2		1 0	NS	15	1541	Glu 1541 ter	
PISA	#8		FS	16	1585	4873 del CA ->	ter 1620
MSK9646			MS	16	1628	Met 1628 Val	
STRANG	8622 ³	4 1	FS	16	1656	5085 del 19 ->	ter 1670
MONTREAL	101	2 2	FS	20	1756	5382 ins C ->	ter 1829
MONTREAL	162	3 1	FS	20	1756	5382 ins C ->	ter 1829
MONTREAL	166	5 2	FS	20	1756	5382 ins C ->	ter 1829
MONTREAL	279	4 0	FS	20	1756	5382 ins C ->	ter 1829
MSKCC	193549	0 3	FS	20	1756	5382 ins C ->	ter 1829
MSK7542			MS	24	1852	Thr 1852 Ser	

¹ FS-Frameshift; NS-Nonsense; MS-Missense; SP-Splice Site.

² For Missense and Nonsense mutations, the mutation description contains: wild type amino acid, affected codon, altered amino acid (or ter). For frameshift mutations, the format is: nucleotide, insertion or deletion, specific nucleotides changed (if <3) or number inserted or deleted (if >2) and the amino acid (accounting for the insertion or deletion) in which the frameshift results in a termination signal. Nucleotides refer to the BRCA1 cDNA sequence in GENBANK under Accession No. U-14680.

³ The mutation in this family was independently identified in both the Myriad and University of Pennsylvania Labs.

⁴ The mutation identified in this tumor was also found in the germline of the individual.

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TABLE 15

Frequency of Two Common BRCA1 Mutations

5	Set	Number Studied	Number of Mutations Found	
			<u>185 del AG</u>	<u>5382 ins C</u>
	USC-1	59	4	1
	MSK/UT-2	109	3	0
	GLASGOW-2	100	Not tested	3
10	GLASGOW-3	100	Not tested	2
	CRC-OV	250	Not tested	1

TABLE 16

Observed Frequency of Different Types of Mutations

15	Mutation Type	Number (Percent)	
		<u>Distinct Mutations¹</u>	<u>All Mutations²</u>
20	Frameshift	42 (65)	81 (72)
	Nonsense	10 (16)	13 (12)
	Missense	9 (14)	14 (12)
	Other	3 (5)	5 (4)

¹ Identical mutations are counted only once in this column.

² Each sample in which a mutation has been identified is counted in this column.

TABLE 17

Distribution of Identified Mutations in BRCA1 Coding Sequence

35	Mutations	Amino Acids		
		<u>1-621</u>	<u>622-1242</u>	<u>1243-1863</u>
	Distinct	18	23	21
	All	44	28	39

40

Mutations have been found in many different regions of the gene - phenotypically severe mutations have been found both in the extreme 5' end of BRCA1 as well as in the extreme 3' portion of the gene. One such mutation found in a family with seven early-onset breast cancer cases produces a protein that is only missing the terminal 10 amino acids, indicating that this region of BRCA1 plays a role in normal gene function. It is noteworthy the overwhelming majority of alterations in BRCA1 have been either frameshift or nonsense mutations resulting in an unstable or truncated protein product.

In BRCA1, to date, two mutations appear to be relatively common. The *5382 ins C* BRCA1 mutation in codon 1756 and the *185 del AG* mutation in codon 23 were identified by direct sequencing in seven (10%) and eight (12%) of the 68 probands studied in the initial studies in which mutations were identified, respectively. In addition to these common mutations, additional mutations have been found in more than one family by a complete screen of the cDNA. Many of the probands screened to date for BRCA1 mutations were selected for having a high prior probability of having such mutations. Thus the mutations found in this set may not be representative of those which would be identified in other sets of patients. However, the two most frequent BRCA1 mutations (*5382 ins C* and *185 del AG*) have been found multiple times in targeted screening in sets of probands who were either unselected for family history or ascertained with minimal family history.

Besides the mutations shown above, many polymorphisms were also detected during the screening of samples. These polymorphisms are listed in Tables 18 and 19.

Industrial Utility

As previously described above, the present invention provides materials and methods for use in testing BRCA1 alleles of an individual and an interpretation of the normal or predisposing nature of the alleles. Individuals at higher than normal risk might modify their lifestyles appropriately. In the case of BRCA1, the most significant non-genetic risk factor is the protective effect of an early, full term pregnancy. Therefore, women at risk could consider early childbearing or a therapy designed to simulate the hormonal effects of an early full-term pregnancy. Women at high risk would also strive for early detection and would be more highly motivated to learn and practice breast self examination. Such women would also be highly motivated to have regular mammograms, perhaps starting at an earlier age than the general population. Ovarian screening

TABLE 18
Polymorphisms in BRCA1 Genomic DNA Exons

Name	Exon #	Codon	Base Position ¹	Base Change	Effect
PM01	11	356	1186	A ↔ G	gln ↔ arg
PM02	13	1436	4427	T ↔ C	ser ↔ ser
PM03	16	1613	4956	A ↔ G	ser ↔ gly
PM06	11	871	2731	C ↔ T	pro ↔ leu
PM07	11	1183	3667	A ↔ G	lys ↔ arg
PM09	11	694	2201	C ↔ T	ser ↔ ser
PM10	11	771	2430	T ↔ C	leu ↔ leu
PM12	16	1561	4801	C ↔ T	thr ↔ ile
PM14	11	1038	3233	A ↔ G	glu ↔ glu
PM17	9	197	710	C ↔ T	cys ↔ cys
PM18	11	693	2196	G ↔ A	asp ↔ asn
PM19	11	841	2640	C ↔ T	arg ↔ trp
PM20	11	1040	3238	G ↔ A	ser ↔ asn
PM21	4	61 ²	48 ³	C ↔ T	ala ↔ val
PM22	11	327	1100	A ↔ G	thr ↔ thr
PM23	11	1316	4067	C ↔ A	phe ↔ leu
PM24	11	1008	3143	G ↔ A	met ↔ ile
PM25	11	1316	4067	C ↔ G	phe ↔ leu
PM26	11	1322	4083	A ↔ G	lys ↔ glu
PM27	11	1347	4158	A ↔ G	arg ↔ gly
PM28	11	707	2240	T ↔ C	gly ↔ gly
PM29	11	675	2144	A ↔ C	ala ↔ ala

¹ Base position as shown in SEQ ID NO:1

² Codon number with exon 4 included in the coding region

³ Base position as shown in SEQ ID NO:11 (exon 4 alone)

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TABLE 19
Polymorphisms in BRCA1 Genomic DNA Introns

Name	Intron #	Base Position ¹	Base Change	Effect
PM04	11	15284	C ↔ A	unknown
PM05	18	20334	A ↔ G	unknown
PM11	16	19231	G ↔ A	unknown
PM15	8	9106	del T	unknown
PM16	22	22914	T ↔ C	unknown
PMA02.1	1	1295	G ↔ A	unknown
PMA03.1	2	2141	G ↔ C	unknown
PMA06.1	5	3653	A ↔ G	unknown
PMA07.1	7	insert between 4391-4392	TTC	unknown
PMA08.1	7	6538	C ↔ T	unknown
PMA08.2	8	6823	A ↔ T	unknown
PMA09.2	9	9376	T ↔ C	unknown
PMA13.1	13	16243	G ↔ A	unknown
PMA15.1	14	insert between 17335-17336	CCAAC	unknown
PMA15.2	14	17399	A ↔ T	unknown
PMA15.3	14	17473	C ↔ G	unknown
PMA18.1	17	20138	C ↔ T	unknown
PMA22.1	21	22680	A ↔ G	unknown

¹ Base position as shown in Figures 10A-H

could also be undertaken at greater frequency. Diagnostic methods based on sequence analysis of the BRCA1 locus could also be applied to tumor detection and classification. Sequence analysis could be used to diagnose precursor lesions. With the evolution of the method and the accumulation of information about BRCA1 and other causative loci, it could become possible to
5 separate cancers into benign and malignant.

Women with breast cancers may follow different surgical procedures if they are predisposed, and therefore likely to have additional cancers, than if they are not predisposed. Other therapies may be developed, using either peptides or small molecules (rational drug design). Peptides could be the missing gene product itself or a portion of the missing gene product. Alternatively, the
10 therapeutic agent could be another molecule that mimics the deleterious gene's function, either a peptide or a nonpeptidic molecule that seeks to counteract the deleterious effect of the inherited locus. The therapy could also be gene based, through introduction of a normal BRCA1 allele into individuals to make a protein which will counteract the effect of the deleterious allele. These gene therapies may take many forms and may be directed either toward preventing the tumor from
15 forming, curing a cancer once it has occurred, or stopping a cancer from metastasizing.

It will be appreciated that the methods and compositions of the instant invention can be incorporated in the form of a variety of embodiments, only a few of which are disclosed herein. It will be apparent to the artisan that other embodiments exist and do not depart from the spirit of the
20 invention. Thus, the described embodiments are illustrative and should not be construed as restrictive.

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List of Patents and Patent Applications:

- U.S. Patent No. 3,817,837
- U.S. Patent No. 3,850,752
- U.S. Patent No. 3,939,350
- U.S. Patent No. 3,996,345
- U.S. Patent No. 4,275,149
- U.S. Patent No. 4,277,437
- U.S. Patent No. 4,366,241
- U.S. Patent No. 4,376,110
- U.S. Patent No. 4,486,530

U.S. Patent No. 4,683,195

U.S. Patent No. 4,683,202

U.S. Patent No. 4,816,567

U.S. Patent No. 4,868,105

U.S. Patent No. 5,252,479

EPO Publication No. 225,807

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Hitzeman *et al.*, EP 73,675A

PCT published application WO 93/07282

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

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- (ii) TITLE OF INVENTION: In Vivo Mutations and Polymorphisms
in the 17q-Linked Breast and Ovarian Cancer
Susceptibility Gene
- (iii) NUMBER OF SEQUENCES: 85
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 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.30
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 - (A) APPLICATION NUMBER:
 - (B) FILING DATE:
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 - (A) APPLICATION NUMBER: US
 - (B) FILING DATE: 07-JUN-1995
- (vii) PRIOR APPLICATION DATA:
 - (A) APPLICATION NUMBER: US 08/409,305
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- (vii) PRIOR APPLICATION DATA:
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- (A) TELEPHONE: 202-962-4810
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(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 5914 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(ix) FEATURE:

- (A) NAME/KEY: CDS
 (B) LOCATION: 120..5711

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

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ATG GAT TTA TCT GCT CTT CGC GTT GAA GAA GTA CAA AAT GTC ATT AAT	167
Met Asp Leu Ser Ala Leu Arg Val Glu Glu Val Gln Asn Val Ile Asn	
1 5 10 15	
GCT ATG CAG AAA ATC TTA GAG TGT CCC ATC TGT CTG GAG TTG ATC AAG	215
Ala Met Gln Lys Ile Leu Glu Cys Pro Ile Cys Leu Glu Leu Ile Lys	
20 25 30	
GAA CCT GTC TCC ACA AAG TGT GAC CAC ATA TTT TGC AAA TTT TGC ATG	263
Glu Pro Val Ser Thr Lys Cys Asp His Ile Phe Cys Lys Phe Cys Met	
35 40 45	

-120-

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CTA ATT ATA GGA GCA TTT GTT ACT GAG CCA CAG ATA ATA CAA GAG CGT Leu Ile Ile Gly Ala Phe Val Thr Glu Pro Gln Ile Ile Gln Glu Arg 485 490 495	1607
CCC CTC ACA AAT AAA TTA AAG CGT AAA AGG AGA CCT ACA TCA GGC CTT Pro Leu Thr Asn Lys Leu Lys Arg Lys Arg Arg Pro Thr Ser Gly Leu 500 505 510	1655
CAT CCT GAG GAT TTT ATC AAG AAA GCA GAT TTG GCA GTT CAA AAG ACT His Pro Glu Asp Phe Ile Lys Lys Ala Asp Leu Ala Val Gln Lys Thr 515 520 525	1703
CCT GAA ATG ATA AAT CAG GGA ACT AAC CAA ACG GAG CAG AAT GGT CAA Pro Glu Met Ile Asn Gln Gly Thr Asn Gln Thr Glu Gln Asn Gly Gln 530 535 540	1751
GTG ATG AAT ATT ACT AAT AGT GGT CAT GAG AAT AAA ACA AAA GGT GAT Val Met Asn Ile Thr Asn Ser Gly His Glu Asn Lys Thr Lys Gly Asp 545 550 555 560	1799
TCT ATT CAG AAT GAG AAA AAT CCT AAC CCA ATA GAA TCA CTC GAA AAA Ser Ile Gln Asn Glu Lys Asn Pro Asn Pro Ile Glu Ser Leu Glu Lys 565 570 575	1847
GAA TCT GCT TTC AAA ACG AAA GCT GAA CCT ATA AGC AGC AGT ATA AGC Glu Ser Ala Phe Lys Thr Lys Ala Glu Pro Ile Ser Ser Ser Ile Ser 580 585 590	1895
AAT ATG GAA CTC GAA TTA AAT ATC CAC AAT TCA AAA GCA CCT AAA AAG Asn Met Glu Leu Glu Leu Asn Ile His Asn Ser Lys Ala Pro Lys Lys 595 600 605	1943
AAT AGG CTG AGG AGG AAG TCT TCT ACC AGG CAT ATT CAT GCG CTT GAA Asn Arg Leu Arg Arg Lys Ser Ser Thr Arg His Ile His Ala Leu Glu 610 615 620	1991
CTA GTA GTC AGT AGA AAT CTA AGC CCA CCT AAT TGT ACT GAA TTG CAA Leu Val Val Ser Arg Asn Leu Ser Pro Pro Asn Cys Thr Glu Leu Gln 625 630 635 640	2039
ATT GAT AGT TGT TCT AGC AGT GAA GAG ATA AAG AAA AAA AAG TAC AAC Ile Asp Ser Cys Ser Ser Ser Glu Glu Ile Lys Lys Lys Lys Tyr Asn 645 650 655	2087
CAA ATG CCA GTC AGG CAC AGC AGA AAC CTA CAA CTC ATG GAA GGT AAA Gln Met Pro Val Arg His Ser Arg Asn Leu Gln Leu Met Glu Gly Lys 660 665 670	2135
GAA CCT GCA ACT GGA GCC AAG AAG AGT AAC AAG CCA AAT GAA CAG ACA Glu Pro Ala Thr Gly Ala Lys Lys Ser Asn Lys Pro Asn Glu Gln Thr 675 680 685	2183
AGT AAA AGA CAT GAC AGC GAT ACT TTC CCA GAG CTG AAG TTA ACA AAT Ser Lys Arg His Asp Ser Asp Thr Phe Pro Glu Leu Lys Leu Thr Asn 690 695 700	2231

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GCA CCT GGT TCT TTT ACT AAG TGT TCA AAT ACC AGT GAA CTT AAA GAA Ala Pro Gly Ser Phe Thr Lys Cys Ser Asn Thr Ser Glu Leu Lys Glu 705 710 715 720	2279
TTT GTC AAT CCT AGC CTT CCA AGA GAA GAA AAA GAA GAG AAA CTA GAA Phe Val Asn Pro Ser Leu Pro Arg Glu Glu Lys Glu Glu Lys Leu Glu 725 730 735	2327
ACA GTT AAA GTG TCT AAT AAT GCT GAA GAC CCC AAA GAT CTC ATG TTA Thr Val Lys Val Ser Asn Asn Ala Glu Asp Pro Lys Asp Leu Met Leu 740 745 750	2375
AGT GGA GAA AGG GTT TTG CAA ACT GAA AGA TCT GTA GAG AGT AGC AGT Ser Gly Glu Arg Val Leu Gln Thr Glu Arg Ser Val Glu Ser Ser Ser 755 760 765	2423
ATT TCA TTG GTA CCT GGT ACT GAT TAT GGC ACT CAG GAA AGT ATC TCG Ile Ser Leu Val Pro Gly Thr Asp Tyr Gly Thr Gln Glu Ser Ile Ser 770 775 780	2471
TTA CTG GAA GTT AGC ACT CTA GGG AAG GCA AAA ACA GAA CCA AAT AAA Leu Leu Glu Val Ser Thr Leu Gly Lys Ala Lys Thr Glu Pro Asn Lys 785 790 795 800	2519
TGT GTG AGT CAG TGT GCA GCA TTT GAA AAC CCC AAG GGA CTA ATT CAT Cys Val Ser Gln Cys Ala Ala Phe Glu Asn Pro Lys Gly Leu Ile His 805 810 815	2567
GGT TGT TCC AAA GAT AAT AGA AAT GAC ACA GAA GGC TTT AAG TAT CCA Gly Cys Ser Lys Asp Asn Arg Asn Asp Thr Glu Gly Phe Lys Tyr Pro 820 825 830	2615
TTG GGA CAT GAA GTT AAC CAC AGT CGG GAA ACA AGC ATA GAA ATG GAA Leu Gly His Glu Val Asn His Ser Arg Glu Thr Ser Ile Glu Met Glu 835 840 845	2663
GAA AGT GAA CTT GAT GCT CAG TAT TTG CAG AAT ACA TTC AAG GTT TCA Glu Ser Glu Leu Asp Ala Gln Tyr Leu Gln Asn Thr Phe Lys Val Ser 850 855 860	2711
AAG CGC CAG TCA TTT GCT CCG TTT TCA AAT CCA GGA AAT GCA GAA GAG Lys Arg Gln Ser Phe Ala Pro Phe Ser Asn Pro Gly Asn Ala Glu Glu 865 870 875 880	2759
GAA TGT GCA ACA TTC TCT GCC CAC TCT GGG TCC TTA AAG AAA CAA AGT Glu Cys Ala Thr Phe Ser Ala His Ser Gly Ser Leu Lys Lys Gln Ser 885 890 895	2807
CCA AAA GTC ACT TTT GAA TGT GAA CAA AAG GAA GAA AAT CAA GGA AAG Pro Lys Val Thr Phe Glu Cys Glu Gln Lys Glu Glu Asn Gln Gly Lys 900 905 910	2855

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AAT GAG TCT AAT ATC AAG CCT GTA CAG ACA GTT AAT ATC ACT GCA GGC Asn Glu Ser Asn Ile Lys Pro Val Gln Thr Val Asn Ile Thr Ala Gly 915 920 925	2903
TTT CCT GTG GTT GGT CAG AAA GAT AAG CCA GTT GAT AAT GCC AAA TGT Phe Pro Val Val Gly Gln Lys Asp Lys Pro Val Asp Asn Ala Lys Cys 930 935 940	2951
AGT ATC AAA GGA GGC TCT AGG TTT TGT CTA TCA TCT CAG TTC AGA GGC Ser Ile Lys Gly Gly Ser Arg Phe Cys Leu Ser Ser Gln Phe Arg Gly 945 950 955 960	2999
AAC GAA ACT GGA CTC ATT ACT CCA AAT AAA CAT GGA CTT TTA CAA AAC Asn Glu Thr Gly Leu Ile Thr Pro Asn Lys His Gly Leu Leu Gln Asn 965 970 975	3047
CCA TAT CGT ATA CCA CCA CTT TTT CCC ATC AAG TCA TTT GTT AAA ACT Pro Tyr Arg Ile Pro Pro Leu Phe Pro Ile Lys Ser Phe Val Lys Thr 980 985 990	3095
AAA TGT AAG AAA AAT CTG CTA GAG GAA AAC TTT GAG GAA CAT TCA ATG Lys Cys Lys Lys Asn Leu Leu Glu Glu Asn Phe Glu Glu His Ser Met 995 1000 1005	3143
TCA CCT GAA AGA GAA ATG GGA AAT GAG AAC ATT CCA AGT ACA GTG AGC Ser Pro Glu Arg Glu Met Gly Asn Glu Asn Ile Pro Ser Thr Val Ser 1010 1015 1020	3191
ACA ATT AGC CGT AAT AAC ATT AGA GAA AAT GTT TTT AAA GAA GCC AGC Thr Ile Ser Arg Asn Asn Ile Arg Glu Asn Val Phe Lys Glu Ala Ser 1025 1030 1035 1040	3239
TCA AGC AAT ATT AAT GAA GTA GGT TCC AGT ACT AAT GAA GTG GGC TCC Ser Ser Asn Ile Asn Glu Val Gly Ser Ser Thr Asn Glu Val Gly Ser 1045 1050 1055	3287
AGT ATT AAT GAA ATA GGT TCC AGT GAT GAA AAC ATT CAA GCA GAA CTA Ser Ile Asn Glu Ile Gly Ser Ser Asp Glu Asn Ile Gln Ala Glu Leu 1060 1065 1070	3335
GGT AGA AAC AGA GGG CCA AAA TTG AAT GCT ATG CTT AGA TTA GGG GTT Gly Arg Asn Arg Gly Pro Lys Leu Asn Ala Met Leu Arg Leu Gly Val 1075 1080 1085	3383
TTG CAA CCT GAG GTC TAT AAA CAA AGT CTT CCT GGA AGT AAT TGT AAG Leu Gln Pro Glu Val Tyr Lys Gln Ser Leu Pro Gly Ser Asn Cys Lys 1090 1095 1100	3431
CAT CCT GAA ATA AAA AAG CAA GAA TAT GAA GAA GTA GTT CAG ACT GTT His Pro Glu Ile Lys Lys Gln Glu Tyr Glu Glu Val Val Gln Thr Val 1105 1110 1115 1120	3479
AAT ACA GAT TTC TCT CCA TAT CTG ATT TCA GAT AAC TTA GAA CAG CCT Asn Thr Asp Phe Ser Pro Tyr Leu Ile Ser Asp Asn Leu Glu Gln Pro 1125 1130 1135	3527

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ATG GGA AGT AGT CAT GCA TCT CAG GTT TGT TCT GAG ACA CCT GAT GAC Met Gly Ser Ser His Ala Ser Gln Val Cys Ser Glu Thr Pro Asp Asp 1140 1145 1150	3575
CTG TTA GAT GAT GGT GAA ATA AAG GAA GAT ACT AGT TTT GCT GAA AAT Leu Leu Asp Asp Gly Glu Ile Lys Glu Asp Thr Ser Phe Ala Glu Asn 1155 1160 1165	3623
GAC ATT AAG GAA AGT TCT GCT GTT TTT AGC AAA AGC GTC CAG AAA GGA Asp Ile Lys Glu Ser Ser Ala Val Phe Ser Lys Ser Val Gln Lys Gly 1170 1175 1180	3671
GAG CTT AGC AGG AGT CCT AGC CCT TTC ACC CAT ACA CAT TTG GCT CAG Glu Leu Ser Arg Ser Pro Ser Pro Phe Thr His Thr His Leu Ala Gln 1185 1190 1195 1200	3719
GGT TAC CGA AGA GGG GCC AAG AAA TTA GAG TCC TCA GAA GAG AAC TTA Gly Tyr Arg Arg Gly Ala Lys Lys Leu Glu Ser Ser Glu Glu Asn Leu 1205 1210 1215	3767
TCT AGT GAG GAT GAA GAG CTT CCC TGC TTC CAA CAC TTG TTA TTT GGT Ser Ser Glu Asp Glu Glu Leu Pro Cys Phe Gln His Leu Leu Phe Gly 1220 1225 1230	3815
AAA GTA AAC AAT ATA CCT TCT CAG TCT ACT AGG CAT AGC ACC GTT GCT Lys Val Asn Asn Ile Pro Ser Gln Ser Thr Arg His Ser Thr Val Ala 1235 1240 1245	3863
ACC GAG TGT CTG TCT AAG AAC ACA GAG GAG AAT TTA TTA TCA TTG AAG Thr Glu Cys Leu Ser Lys Asn Thr Glu Glu Asn Leu Leu Ser Leu Lys 1250 1255 1260	3911
AAT AGC TTA AAT GAC TGC AGT AAC CAG GTA ATA TTG GCA AAG GCA TCT Asn Ser Leu Asn Asp Cys Ser Asn Gln Val Ile Leu Ala Lys Ala Ser 1265 1270 1275 1280	3959
CAG GAA CAT CAC CTT AGT GAG GAA ACA AAA TGT TCT GCT AGC TTG TTT Gln Glu His His Leu Ser Glu Glu Thr Lys Cys Ser Ala Ser Leu Phe 1285 1290 1295	4007
TCT TCA CAG TGC AGT GAA TTG GAA GAC TTG ACT GCA AAT ACA AAC ACC Ser Ser Gln Cys Ser Glu Leu Glu Asp Leu Thr Ala Asn Thr Asn Thr 1300 1305 1310	4055
CAG GAT CCT TTC TTG ATT GGT TCT TCC AAA CAA ATG AGG CAT CAG TCT Gln Asp Pro Phe Leu Ile Gly Ser Ser Lys Gln Met Arg His Gln Ser 1315 1320 1325	4103
GAA AGC CAG GGA GTT GGT CTG AGT GAC AAG GAA TTG GTT TCA GAT GAT Glu Ser Gln Gly Val Gly Leu Ser Asp Lys Glu Leu Val Ser Asp Asp 1330 1335 1340	4151

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GAA GAA AGA GGA ACG GGC TTG GAA GAA AAT AAT CAA GAA GAG CAA AGC Glu Glu Arg Gly Thr Gly Leu Glu Glu Asn Asn Gln Glu Glu Gln Ser 1345 1350 1355 1360	4199
ATG GAT TCA AAC TTA GGT GAA GCA GCA TCT GGG TGT GAG AGT GAA ACA Met Asp Ser Asn Leu Gly Glu Ala Ala Ser Gly Cys Glu Ser Glu Thr 1365 1370 1375	4247
AGC GTC TCT GAA GAC TGC TCA GGG CTA TCC TCT CAG AGT GAC ATT TTA Ser Val Ser Glu Asp Cys Ser Gly Leu Ser Ser Gln Ser Asp Ile Leu 1380 1385 1390	4295
ACC ACT CAG CAG AGG GAT ACC ATG CAA CAT AAC CTG ATA AAG CTC CAG Thr Thr Gln Gln Arg Asp Thr Met Gln His Asn Leu Ile Lys Leu Gln 1395 1400 1405	4343
CAG GAA ATG GCT GAA CTA GAA GCT GTG TTA GAA CAG CAT GGG AGC CAG Gln Glu Met Ala Glu Leu Glu Ala Val Leu Glu Gln His Gly Ser Gln 1410 1415 1420	4391
CCT TCT AAC AGC TAC CCT TCC ATC ATA AGT GAC TCT TCT GCC CTT GAG Pro Ser Asn Ser Tyr Pro Ser Ile Ile Ser Asp Ser Ser Ala Leu Glu 1425 1430 1435 1440	4439
GAC CTG CGA AAT CCA GAA CAA AGC ACA TCA GAA AAA GCA GTA TTA ACT Asp Leu Arg Asn Pro Glu Gln Ser Thr Ser Glu Lys Ala Val Leu Thr 1445 1450 1455	4487
TCA CAG AAA AGT AGT GAA TAC CCT ATA AGC CAG AAT CCA GAA GGC CTT Ser Gln Lys Ser Ser Glu Tyr Pro Ile Ser Gln Asn Pro Glu Gly Leu 1460 1465 1470	4535
TCT GCT GAC AAG TTT GAG GTG TCT GCA GAT AGT TCT ACC AGT AAA AAT Ser Ala Asp Lys Phe Glu Val Ser Ala Asp Ser Ser Thr Ser Lys Asn 1475 1480 1485	4583
AAA GAA CCA GGA GTG GAA AGG TCA TCC CCT TCT AAA TGC CCA TCA TTA Lys Glu Pro Gly Val Glu Arg Ser Ser Pro Ser Lys Cys Pro Ser Leu 1490 1495 1500	4631
GAT GAT AGG TGG TAC ATG CAC AGT TGC TCT GGG AGT CTT CAG AAT AGA Asp Asp Arg Trp Tyr Met His Ser Cys Ser Gly Ser Leu Gln Asn Arg 1505 1510 1515 1520	4679
AAC TAC CCA TCT CAA GAG GAG CTC ATT AAG GTT GTT GAT GTG GAG GAG Asn Tyr Pro Ser Gln Glu Glu Leu Ile Lys Val Val Asp Val Glu Glu 1525 1530 1535	4727
CAA CAG CTG GAA GAG TCT GGG CCA CAC GAT TTG ACG GAA ACA TCT TAC Gln Gln Leu Glu Glu Ser Gly Pro His Asp Leu Thr Glu Thr Ser Tyr 1540 1545 1550	4775
TTG CCA AGG CAA GAT CTA GAG GGA ACC CCT TAC CTG GAA TCT GGA ATC Leu Pro Arg Gln Asp Leu Glu Gly Thr Pro Tyr Leu Glu Ser Gly Ile 1555 1560 1565	4823

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AGC CTC TTC TCT GAT GAC CCT GAA TCT GAT CCT TCT GAA GAC AGA GCC Ser Leu Phe Ser Asp Asp Pro Glu Ser Asp Pro Ser Glu Asp Arg Ala 1570 1575 1580	4871
CCA GAG TCA GCT CGT GTT GGC AAC ATA CCA TCT TCA ACC TCT GCA TTG Pro Glu Ser Ala Arg Val Gly Asn Ile Pro Ser Ser Thr Ser Ala Leu 1585 1590 1595 1600	4919
AAA GTT CCC CAA TTG AAA GTT GCA GAA TCT GCC CAG AGT CCA GCT GCT Lys Val Pro Gln Leu Lys Val Ala Glu Ser Ala Gln Ser Pro Ala Ala 1605 1610 1615	4967
GCT CAT ACT ACT GAT ACT GCT GGG TAT AAT GCA ATG GAA GAA AGT GTG Ala His Thr Thr Asp Thr Ala Gly Tyr Asn Ala Met Glu Glu Ser Val 1620 1625 1630	5015
AGC AGG GAG AAG CCA GAA TTG ACA GCT TCA ACA GAA AGG GTC AAC AAA Ser Arg Glu Lys Pro Glu Leu Thr Ala Ser Thr Glu Arg Val Asn Lys 1635 1640 1645	5063
AGA ATG TCC ATG GTG GTG TCT GGC CTG ACC CCA GAA GAA TTT ATG CTC Arg Met Ser Met Val Val Ser Gly Leu Thr Pro Glu Glu Phe Met Leu 1650 1655 1660	5111
GTG TAC AAG TTT GCC AGA AAA CAC CAC ATC ACT TTA ACT AAT CTA ATT Val Tyr Lys Phe Ala Arg Lys His His Ile Thr Leu Thr Asn Leu Ile 1665 1670 1675 1680	5159
ACT GAA GAG ACT ACT CAT GTT GTT ATG AAA ACA GAT GCT GAG TTT GTG Thr Glu Glu Thr Thr His Val Val Met Lys Thr Asp Ala Glu Phe Val 1685 1690 1695	5207
TGT GAA CGG ACA CTG AAA TAT TTT CTA GGA ATT GCG GGA GGA AAA TGG Cys Glu Arg Thr Leu Lys Tyr Phe Leu Gly Ile Ala Gly Gly Lys Trp 1700 1705 1710	5255
GTA GTT AGC TAT TTC TGG GTG ACC CAG TCT ATT AAA GAA AGA AAA ATG Val Val Ser Tyr Phe Trp Val Thr Gln Ser Ile Lys Glu Arg Lys Met 1715 1720 1725	5303
CTG AAT GAG CAT GAT TTT GAA GTC AGA GGA GAT GTG GTC AAT GGA AGA Leu Asn Glu His Asp Phe Glu Val Arg Gly Asp Val Val Asn Gly Arg 1730 1735 1740	5351
AAC CAC CAA GGT CCA AAG CGA GCA AGA GAA TCC CAG GAC AGA AAG ATC Asn His Gln Gly Pro Lys Arg Ala Arg Glu Ser Gln Asp Arg Lys Ile 1745 1750 1755 1760	5399
TTC AGG GGG CTA GAA ATC TGT TGC TAT GGG CCC TTC ACC AAC ATG CCC Phe Arg Gly Leu Glu Ile Cys Cys Tyr Gly Pro Phe Thr Asn Met Pro 1765 1770 1775	5447

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ACA GAT CAA CTG GAA TGG ATG GTA CAG CTG TGT GGT GCT TCT GTG GTG Thr Asp Gln Leu Glu Trp Met Val Gln Leu Cys Gly Ala Ser Val Val 1780 1785 1790	5495
AAG GAG CTT TCA TCA TTC ACC CTT GGC ACA GGT GTC CAC CCA ATT GTG Lys Glu Leu Ser Ser Phe Thr Leu Gly Thr Gly Val His Pro Ile Val 1795 1800 1805	5543
GTT GTG CAG CCA GAT GCC TGG ACA GAG GAC AAT GGC TTC CAT GCA ATT Val Val Gln Pro Asp Ala Trp Thr Glu Asp Asn Gly Phe His Ala Ile 1810 1815 1820	5591
GGG CAG ATG TGT GAG GCA CCT GTG GTG ACC CGA GAG TGG GTG TTG GAC Gly Gln Met Cys Glu Ala Pro Val Val Thr Arg Glu Trp Val Leu Asp 1825 1830 1835 1840	5639
AGT GTA GCA CTC TAC CAG TGC CAG GAG CTG GAC ACC TAC CTG ATA CCC Ser Val Ala Leu Tyr Gln Cys Gln Glu Leu Asp Thr Tyr Leu Ile Pro 1845 1850 1855	5687
CAG ATC CCC CAC AGC CAC TAC TGA CTGCAGCCAG CCACAGGTAC AGAGCCACAG Gln Ile Pro His Ser His Tyr *	5741
1860	
GACCCCAAGA ATGAGCTTAC AAAGTGGCCT TTCCAGGCCC TGGGAGCTCC TCTCACTCTT	5801
CAGTCCTTCT ACTGTCCTGG CTACTAAATA TTTTATGTAC ATCAGCCTGA AAAGGACTTC	5861
TGGCTATGCA AGGGTCCCTT AAAGATTTTC TGCTTGAAGT CTCCCTTGGA AAT	5914

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1864 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Met Asp Leu Ser Ala Leu Arg Val Glu Glu Val Gln Asn Val Ile Asn 1 5 10 15
Ala Met Gln Lys Ile Leu Glu Cys Pro Ile Cys Leu Glu Leu Ile Lys 20 25 30
Glu Pro Val Ser Thr Lys Cys Asp His Ile Phe Cys Lys Phe Cys Met 35 40 45
Leu Lys Leu Leu Asn Gln Lys Lys Gly Pro Ser Gln Cys Pro Leu Cys 50 55 60

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Lys Asn Asp Ile Thr Lys Arg Ser Leu Gln Glu Ser Thr Arg Phe Ser
 65 70 75 80
 Gln Leu Val Glu Glu Leu Leu Lys Ile Ile Cys Ala Phe Gln Leu Asp
 85 90 95
 Thr Gly Leu Glu Tyr Ala Asn Ser Tyr Asn Phe Ala Lys Lys Glu Asn
 100 105 110
 Asn Ser Pro Glu His Leu Lys Asp Glu Val Ser Ile Ile Gln Ser Met
 115 120 125
 Gly Tyr Arg Asn Arg Ala Lys Arg Leu Leu Gln Ser Glu Pro Glu Asn
 130 135 140
 Pro Ser Leu Gln Glu Thr Ser Leu Ser Val Gln Leu Ser Asn Leu Gly
 145 150 155 160
 Thr Val Arg Thr Leu Arg Thr Lys Gln Arg Ile Gln Pro Gln Lys Thr
 165 170 175
 Ser Val Tyr Ile Glu Leu Gly Ser Asp Ser Ser Glu Asp Thr Val Asn
 180 185 190
 Lys Ala Thr Tyr Cys Ser Val Gly Asp Gln Glu Leu Leu Gln Ile Thr
 195 200 205
 Pro Gln Gly Thr Arg Asp Glu Ile Ser Leu Asp Ser Ala Lys Lys Ala
 210 215 220
 Ala Cys Glu Phe Ser Glu Thr Asp Val Thr Asn Thr Glu His His Gln
 225 230 235 240
 Pro Ser Asn Asn Asp Leu Asn Thr Thr Glu Lys Arg Ala Ala Glu Arg
 245 250 255
 His Pro Glu Lys Tyr Gln Gly Ser Ser Val Ser Asn Leu His Val Glu
 260 265 270
 Pro Cys Gly Thr Asn Thr His Ala Ser Ser Leu Gln His Glu Asn Ser
 275 280 285
 Ser Leu Leu Leu Thr Lys Asp Arg Met Asn Val Glu Lys Ala Glu Phe
 290 295 300
 Cys Asn Lys Ser Lys Gln Pro Gly Leu Ala Arg Ser Gln His Asn Arg
 305 310 315 320
 Trp Ala Gly Ser Lys Glu Thr Cys Asn Asp Arg Arg Thr Pro Ser Thr
 325 330 335
 Glu Lys Lys Val Asp Leu Asn Ala Asp Pro Leu Cys Glu Arg Lys Glu
 340 345 350

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Trp Asn Lys Gln Lys Leu Pro Cys Ser Glu Asn Pro Arg Asp Thr Glu
 355 360 365
 Asp Val Pro Trp Ile Thr Leu Asn Ser Ser Ile Gln Lys Val Asn Glu
 370 375 380
 Trp Phe Ser Arg Ser Asp Glu Leu Leu Gly Ser Asp Asp Ser His Asp
 385 390 395 400
 Gly Glu Ser Glu Ser Asn Ala Lys Val Ala Asp Val Leu Asp Val Leu
 405 410 415
 Asn Glu Val Asp Glu Tyr Ser Gly Ser Ser Glu Lys Ile Asp Leu Leu
 420 425 430
 Ala Ser Asp Pro His Glu Ala Leu Ile Cys Lys Ser Glu Arg Val His
 435 440 445
 Ser Lys Ser Val Glu Ser Asn Ile Glu Asp Lys Ile Phe Gly Lys Thr
 450 455 460
 Tyr Arg Lys Lys Ala Ser Leu Pro Asn Leu Ser His Val Thr Glu Asn
 465 470 475 480
 Leu Ile Ile Gly Ala Phe Val Thr Glu Pro Gln Ile Ile Gln Glu Arg
 485 490 495
 Pro Leu Thr Asn Lys Leu Lys Arg Lys Arg Arg Pro Thr Ser Gly Leu
 500 505 510
 His Pro Glu Asp Phe Ile Lys Lys Ala Asp Leu Ala Val Gln Lys Thr
 515 520 525
 Pro Glu Met Ile Asn Gln Gly Thr Asn Gln Thr Glu Gln Asn Gly Gln
 530 535 540
 Val Met Asn Ile Thr Asn Ser Gly His Glu Asn Lys Thr Lys Gly Asp
 545 550 555 560
 Ser Ile Gln Asn Glu Lys Asn Pro Asn Pro Ile Glu Ser Leu Glu Lys
 565 570 575
 Glu Ser Ala Phe Lys Thr Lys Ala Glu Pro Ile Ser Ser Ser Ile Ser
 580 585 590
 Asn Met Glu Leu Glu Leu Asn Ile His Asn Ser Lys Ala Pro Lys Lys
 595 600 605
 Asn Arg Leu Arg Arg Lys Ser Ser Thr Arg His Ile His Ala Leu Glu
 610 615 620
 Leu Val Val Ser Arg Asn Leu Ser Pro Pro Asn Cys Thr Glu Leu Gln
 625 630 635 640

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Ile Asp Ser Cys Ser Ser Ser Glu Glu Ile Lys Lys Lys Lys Tyr Asn
 645 650 655

Gln Met Pro Val Arg His Ser Arg Asn Leu Gln Leu Met Glu Gly Lys
 660 665 670

Glu Pro Ala Thr Gly Ala Lys Lys Ser Asn Lys Pro Asn Glu Gln Thr
 675 680 685

Ser Lys Arg His Asp Ser Asp Thr Phe Pro Glu Leu Lys Leu Thr Asn
 690 695 700

Ala Pro Gly Ser Phe Thr Lys Cys Ser Asn Thr Ser Glu Leu Lys Glu
 705 710 715 720

Phe Val Asn Pro Ser Leu Pro Arg Glu Glu Lys Glu Glu Lys Leu Glu
 725 730 735

Thr Val Lys Val Ser Asn Asn Ala Glu Asp Pro Lys Asp Leu Met Leu
 740 745 750

Ser Gly Glu Arg Val Leu Gln Thr Glu Arg Ser Val Glu Ser Ser Ser
 755 760 765

Ile Ser Leu Val Pro Gly Thr Asp Tyr Gly Thr Gln Glu Ser Ile Ser
 770 775 780

Leu Leu Glu Val Ser Thr Leu Gly Lys Ala Lys Thr Glu Pro Asn Lys
 785 790 795 800

Cys Val Ser Gln Cys Ala Ala Phe Glu Asn Pro Lys Gly Leu Ile His
 805 810 815

Gly Cys Ser Lys Asp Asn Arg Asn Asp Thr Glu Gly Phe Lys Tyr Pro
 820 825 830

Leu Gly His Glu Val Asn His Ser Arg Glu Thr Ser Ile Glu Met Glu
 835 840 845

Glu Ser Glu Leu Asp Ala Gln Tyr Leu Gln Asn Thr Phe Lys Val Ser
 850 855 860

Lys Arg Gln Ser Phe Ala Pro Phe Ser Asn Pro Gly Asn Ala Glu Glu
 865 870 875 880

Glu Cys Ala Thr Phe Ser Ala His Ser Gly Ser Leu Lys Lys Gln Ser
 885 890 895

Pro Lys Val Thr Phe Glu Cys Glu Gln Lys Glu Glu Asn Gln Gly Lys
 900 905 910

Asn Glu Ser Asn Ile Lys Pro Val Gln Thr Val Asn Ile Thr Ala Gly
 915 920 925

Phe Pro Val Val Gly Gln Lys Asp Lys Pro Val Asp Asn Ala Lys Cys
 930 935 940

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Ser Ile Lys Gly Gly Ser Arg Phe Cys Leu Ser Ser Gln Phe Arg Gly
 945 950 955 960
 Asn Glu Thr Gly Leu Ile Thr Pro Asn Lys His Gly Leu Leu Gln Asn
 965 970 975
 Pro Tyr Arg Ile Pro Pro Leu Phe Pro Ile Lys Ser Phe Val Lys Thr
 980 985 990
 Lys Cys Lys Lys Asn Leu Leu Glu Glu Asn Phe Glu Glu His Ser Met
 995 1000 1005
 Ser Pro Glu Arg Glu Met Gly Asn Glu Asn Ile Pro Ser Thr Val Ser
 1010 1015 1020
 Thr Ile Ser Arg Asn Asn Ile Arg Glu Asn Val Phe Lys Glu Ala Ser
 1025 1030 1035 1040
 Ser Ser Asn Ile Asn Glu Val Gly Ser Ser Thr Asn Glu Val Gly Ser
 1045 1050 1055
 Ser Ile Asn Glu Ile Gly Ser Ser Asp Glu Asn Ile Gln Ala Glu Leu
 1060 1065 1070
 Gly Arg Asn Arg Gly Pro Lys Leu Asn Ala Met Leu Arg Leu Gly Val
 1075 1080 1085
 Leu Gln Pro Glu Val Tyr Lys Gln Ser Leu Pro Gly Ser Asn Cys Lys
 1090 1095 1100
 His Pro Glu Ile Lys Lys Gln Glu Tyr Glu Glu Val Val Gln Thr Val
 1105 1110 1115 1120
 Asn Thr Asp Phe Ser Pro Tyr Leu Ile Ser Asp Asn Leu Glu Gln Pro
 1125 1130 1135
 Met Gly Ser Ser His Ala Ser Gln Val Cys Ser Glu Thr Pro Asp Asp
 1140 1145 1150
 Leu Leu Asp Asp Gly Glu Ile Lys Glu Asp Thr Ser Phe Ala Glu Asn
 1155 1160 1165
 Asp Ile Lys Glu Ser Ser Ala Val Phe Ser Lys Ser Val Gln Lys Gly
 1170 1175 1180
 Glu Leu Ser Arg Ser Pro Ser Pro Phe Thr His Thr His Leu Ala Gln
 1185 1190 1195 1200
 Gly Tyr Arg Arg Gly Ala Lys Lys Leu Glu Ser Ser Glu Glu Asn Leu
 1205 1210 1215
 Ser Ser Glu Asp Glu Glu Leu Pro Cys Phe Gln His Leu Leu Phe Gly
 1220 1225 1230
 Lys Val Asn Asn Ile Pro Ser Gln Ser Thr Arg His Ser Thr Val Ala
 1235 1240 1245

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Thr Glu Cys Leu Ser Lys Asn Thr Glu Glu Asn Leu Leu Ser Leu Lys
 1250 1255 1260

Asn Ser Leu Asn Asp Cys Ser Asn Gln Val Ile Leu Ala Lys Ala Ser
 1265 1270 1275 1280

Gln Glu His His Leu Ser Glu Glu Thr Lys Cys Ser Ala Ser Leu Phe
 1285 1290 1295

Ser Ser Gln Cys Ser Glu Leu Glu Asp Leu Thr Ala Asn Thr Asn Thr
 1300 1305 1310

Gln Asp Pro Phe Leu Ile Gly Ser Ser Lys Gln Met Arg His Gln Ser
 1315 1320 1325

Glu Ser Gln Gly Val Gly Leu Ser Asp Lys Glu Leu Val Ser Asp Asp
 1330 1335 1340

Glu Glu Arg Gly Thr Gly Leu Glu Glu Asn Asn Gln Glu Glu Gln Ser
 1345 1350 1355 1360

Met Asp Ser Asn Leu Gly Glu Ala Ala Ser Gly Cys Glu Ser Glu Thr
 1365 1370 1375

Ser Val Ser Glu Asp Cys Ser Gly Leu Ser Ser Gln Ser Asp Ile Leu
 1380 1385 1390

Thr Thr Gln Gln Arg Asp Thr Met Gln His Asn Leu Ile Lys Leu Gln
 1395 1400 1405

Gln Glu Met Ala Glu Leu Glu Ala Val Leu Glu Gln His Gly Ser Gln
 1410 1415 1420

Pro Ser Asn Ser Tyr Pro Ser Ile Ile Ser Asp Ser Ser Ala Leu Glu
 1425 1430 1435 1440

Asp Leu Arg Asn Pro Glu Gln Ser Thr Ser Glu Lys Ala Val Leu Thr
 1445 1450 1455

Ser Gln Lys Ser Ser Glu Tyr Pro Ile Ser Gln Asn Pro Glu Gly Leu
 1460 1465 1470

Ser Ala Asp Lys Phe Glu Val Ser Ala Asp Ser Ser Thr Ser Lys Asn
 1475 1480 1485

Lys Glu Pro Gly Val Glu Arg Ser Ser Pro Ser Lys Cys Pro Ser Leu
 1490 1495 1500

Asp Asp Arg Trp Tyr Met His Ser Cys Ser Gly Ser Leu Gln Asn Arg
 1505 1510 1515 1520

Asn Tyr Pro Ser Gln Glu Glu Leu Ile Lys Val Val Asp Val Glu Glu
 1525 1530 1535

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Gln Gln Leu Glu Glu Ser Gly Pro His Asp Leu Thr Glu Thr Ser Tyr
 1540 1545 1550
 Leu Pro Arg Gln Asp Leu Glu Gly Thr Pro Tyr Leu Glu Ser Gly Ile
 1555 1560 1565
 Ser Leu Phe Ser Asp Asp Pro Glu Ser Asp Pro Ser Glu Asp Arg Ala
 1570 1575 1580
 Pro Glu Ser Ala Arg Val Gly Asn Ile Pro Ser Ser Thr Ser Ala Leu
 1585 1590 1595 1600
 Lys Val Pro Gln Leu Lys Val Ala Glu Ser Ala Gln Ser Pro Ala Ala
 1605 1610 1615
 Ala His Thr Thr Asp Thr Ala Gly Tyr Asn Ala Met Glu Glu Ser Val
 1620 1625 1630
 Ser Arg Glu Lys Pro Glu Leu Thr Ala Ser Thr Glu Arg Val Asn Lys
 1635 1640 1645
 Arg Met Ser Met Val Val Ser Gly Leu Thr Pro Glu Glu Phe Met Leu
 1650 1655 1660
 Val Tyr Lys Phe Ala Arg Lys His His Ile Thr Leu Thr Asn Leu Ile
 1665 1670 1675 1680
 Thr Glu Glu Thr Thr His Val Val Met Lys Thr Asp Ala Glu Phe Val
 1685 1690 1695
 Cys Glu Arg Thr Leu Lys Tyr Phe Leu Gly Ile Ala Gly Gly Lys Trp
 1700 1705 1710
 Val Val Ser Tyr Phe Trp Val Thr Gln Ser Ile Lys Glu Arg Lys Met
 1715 1720 1725
 Leu Asn Glu His Asp Phe Glu Val Arg Gly Asp Val Val Asn Gly Arg
 1730 1735 1740
 Asn His Gln Gly Pro Lys Arg Ala Arg Glu Ser Gln Asp Arg Lys Ile
 1745 1750 1755 1760
 Phe Arg Gly Leu Glu Ile Cys Cys Tyr Gly Pro Phe Thr Asn Met Pro
 1765 1770 1775
 Thr Asp Gln Leu Glu Trp Met Val Gln Leu Cys Gly Ala Ser Val Val
 1780 1785 1790
 Lys Glu Leu Ser Ser Phe Thr Leu Gly Thr Gly Val His Pro Ile Val
 1795 1800 1805
 Val Val Gln Pro Asp Ala Trp Thr Glu Asp Asn Gly Phe His Ala Ile
 1810 1815 1820
 Gly Gln Met Cys Glu Ala Pro Val Val Thr Arg Glu Trp Val Leu Asp
 1825 1830 1835 1840

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Ser Val Ala Leu Tyr Gln Cys Gln Glu Leu Asp Thr Tyr Leu Ile Pro
1845 1850 1855

Gln Ile Pro His Ser His Tyr *
1860

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(vii) IMMEDIATE SOURCE:

(B) CLONE: s754 A

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

CTAGCCTGGG CAACAAACGA

20

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(vii) IMMEDIATE SOURCE:

(B) CLONE: s754 B

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

GCAGGAAGCA GGAATGGAAC

20

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(2) INFORMATION FOR SEQ ID NO:5:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens
- (vii) IMMEDIATE SOURCE:
 - (B) CLONE: s975 A
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

TAGGAGATGG ATTATTGGTG

20

(2) INFORMATION FOR SEQ ID NO:6:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens
- (vii) IMMEDIATE SOURCE:
 - (B) CLONE: s975 B
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

AGGCAACTTT GCAATGAGTG

20

(2) INFORMATION FOR SEQ ID NO:7:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 22 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

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- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens
- (vii) IMMEDIATE SOURCE:
 - (B) CLONE: tdj1474 A

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

CAGAGTGAGA CCTTGTCTCA AA

22

- (2) INFORMATION FOR SEQ ID NO:8:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 23 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens
- (vii) IMMEDIATE SOURCE:
 - (B) CLONE: tdj1474 B

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

TTCTGCAAAC ACCTTAAACT CAG

23

- (2) INFORMATION FOR SEQ ID NO:9:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens

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(vii) IMMEDIATE SOURCE:
(B) CLONE: tdj1239 A

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

AACCTGGAAG GCAGAGGTTG

20

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

(vii) IMMEDIATE SOURCE:
(B) CLONE: tdj1239 B

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

TCTGTACCTG CTAAGCAGTG G

21

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 111 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

(ix) FEATURE:
(A) NAME/KEY: CDS
(B) LOCATION: 2..111

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

G GKC TTA CTC TGT TGT CCC AGC TGG AGT ACA GWG TGC GAT CAT GAG	46
Xaa Leu Leu Cys Cys Pro Ser Trp Ser Thr Xaa Cys Asp His Glu	
1865 1870 1875	
GCT TAC TGT TGC TTG ACT CCT AGG CTC AAG CGA TCC TAT CAC CTC AGT	94
Ala Tyr Cys Cys Leu Thr Pro Arg Leu Lys Arg Ser Tyr His Leu Ser	
1880 1885 1890 1895	
CTC CAA GTA GCT GGA CT	111
Leu Gln Val Ala Gly	
1900	

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 36 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Xaa Leu Leu Cys Cys Pro Ser Trp Ser Thr Xaa Cys Asp His Glu Ala	
1 5 10 15	
Tyr Cys Cys Leu Thr Pro Arg Leu Lys Arg Ser Tyr His Leu Ser Leu	
20 25 30	
Gln Val Ala Gly	
35	

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1534 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

GAGGCTAGAG GGCAGGCACT TTATGGCAAA CTCAGGTAGA ATTCTTCCTC TTCCGTCTCT	60
TTCCTTTTAC GTCATCGGGG AGACTGGGTG GCAATCGCAG CCCGAGAGAC GCATGGCTCT	120
TTCTGCCCTC CATCCTCTGA TGTACCTTGA TTTCTGATTC TGAGAGGCTG CTGCTTAGCG	180
GTAGCCCCCTT GGTTCCTGTG GCAACGGAAA AGCGCGGGAA TTACAGATAA ATTAAACTG	240
CGACTGCGCG GCGTGAGCTC GCTGAGACTT CCTGGACCCC GCACCAGGCT GTGGGGTTTC	300
TCAGATAACT GGGCCCCCTGC GCTCAGGAGG CCTTCACCCT CTGCTCTGGG TAAAGGTAGT	360
AGAGTCCCGG GAAAGGGACA GGGGGCCCAA GTGATGCTCT GGGGTACTGG CGTGGGAGAG	420
TGGATTTCCG AAGCTGACAG ATGGGTATTC TTTGACGGGG GGTAGGGGCG GAACCTGAGA	480
GGCGTAAGGC GTTGTGAACC CTGGGGAGGG GGGCAGTTTG TAGGTCGCGA GGGGAAGCGCT	540
GAGGATCAGG AAGGGGGCAC TGAGTGTCG TGGGGGAATC CTCGTGATAG GAACTGGAAT	600
ATGCCTTGAG GGGGACACTA TGTCTTTAAA AACGTCGGCT GGTTCATGAGG TCAGGAGTTC	660
CAGACCAGCC TGACCAACGT GGTGAACTC CGTCTCTACT AAAAATACNA AAATTAGCCG	720
GGCGTGGTGC CGCTCCAGCT ACTCAGGAGG CTGAGGCAGG AGAATCGCTA GAACCCGGGA	780
GGCGGAGGTT GCAGTGAGCC GAGATCGCGC CATTGCACTC CAGCCTGGGC GACAGAGCGA	840
GACTGTCTCA AAACAAAACA AAACAAAACA AAACAAAAAA CACCGGCTGG TATGTATGAG	900
AGGATGGGAC CTTGTGGAAG AAGAGGTGCC AGGAATATGT CTGGGAAGGG GAGGAGACAG	960
GATTTTGTGG GAGGGAGAAC TTAAGAACTG GATCCATTTG CGCCATTGAG AAAGCGCAAG	1020
AGGGAAGTAG AGGAGCGTCA GTAGTAACAG ATGCTGCCGG CAGGGATGTG CTTGAGGAGG	1080
ATCCAGAGAT GAGAGCAGGT CACTGGGAAA GGTAGGGGC GGGGAGGCCT TGATTGGTGT	1140
TGTTTTGGTC GTTGTGATT TTGGTTTTAT GCAAGAAAAA GAAAACAACC AGAAACATTG	1200
GAGAAAGCTA AGGCTACCAC CACCTACCCG GTCAGTCACT CCTCTGTAGC TTTCTCTTC	1260
TTGGAGAAAG GAAAAGACCC AAGGGGTTGG CAGCGATATG TGAAAAAATT CAGAATTTAT	1320
GTTGTCTAAT TACAAAAGC AACTTCTAGA ATCTTTAAAA ATAAAGGACG TTGTCATTAG	1380
TTCTTCTGGT TTGTATTATT CTAAAACCTT CCAAATCTTC AAATTTACTT TATTTTAAAA	1440
TGATAAAATG AAGTTGTCAT TTTATAAACC TTTTAAAAAG ATATATATAT ATGTTTTTCT	1500
AATGTGTTAA AGTTCATTGG AACAGAAAGA AATG	1534

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(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1924 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

GAGGCTAGAG GGCAGGCACT TTATGGCAAA CTCAGGTAGA ATTCTTCCTC TTCCGTCTCT	60
TTCTTTTAC GTCATCGGGG AGACTGGGTG GCAATCGCAG CCCGAGAGAC GCATGGCTCT	120
TTCTGCCCTC CATCCTCTGA TGTACCTTGA TTTCGTATTC TGAGAGGCTG CTGCTTAGCG	180
GTAGCCCCCTT GGTTCCTGTG GCAACGGAAA AGCGCGGGAA TTACAGATAA ATTAAACTG	240
CGACTGCGCG GCGTGAGCTC GCTGAGACTT CCTGGACCCC GCACCAGGCT GTGGGGTTTC	300
TCAGATAACT GGGCCCCCTGC GCTCAGGAGG CCTTCACCCT CTGCTCTGGG TAAAGGTAGT	360
AGAGTCCCGG GAAAGGGACA GGGGGCCCAA GTGATGCTCT GGGGTACTGG CGTGGGAGAG	420
TGGATTTCG AAGCTGACAG ATGGGTATTC TTTGACGGGG GGTAGGGGCG GAACCTGAGA	480
GGCGTAAGGC GTTGTGAACC CTGGGGAGGG GGGCAGTTTG TAGGTCGCGA GGAAGCGCT	540
GAGGATCAGG AAGGGGGCAC TGAGTGTCG TGGGGGAATC CTCGTGATAG GAACTGGAAT	600
ATGCCTTGAG GGGGACACTA TGTCTTTAAA AACGTCGGCT GGTGATGAGG TCAGGAGTTC	660
CAGACCAGCC TGACCAACGT GGTGAACTC CGTCTCTACT AAAAATACNA AAATTAGCCG	720
GGCGTGGTGC CGCTCCAGCT ACTCAGGAGG CTGAGGCAGG AGAATCGCTA GAACCCGGA	780
GGCGGAGGTT GCACTGAGCC GAGATCGCGC CATTGCACTC CAGCCTGGGC GACAGAGCGA	840
GACTGTCTCA AAACAAAACA AAACAAAACA AAACAAAAA CACCGGCTGG TATGTATGAG	900
AGGATGGGAC CTTGTGGAAG AAGAGGTGCC AGGAATATGT CTGGGAAGGG GAGGAGACAG	960
GATTTTGTGG GAGGGAGAAC TTAAGAACTG GATCCATTTG CGCCATTGAG AAAGCGCAAG	1020

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AGGGAAGTAG AGGAGCGTCA GTAGTAACAG ATGCTGCCGG CAGGGATGTG CTTGAGGAGG 1080
ATCCAGAGAT GAGAGCAGGT CACTGGGAAA GGTTAGGGGC GGGGAGGCCT TGATTGGTGT 1140
TGGTTTGGTC GTTGTGATT TTGGTTTAT GCAAGAAAAA GAAAACAACC AGAAACATTG 1200
GAGAAAGCTA AGGCTACCAC CACCTACCCG GTCAGTCACT CCTCTGTAGC TTTCTCTTTC 1260
TTGGAGAAAG GAAAAGACCC AAGGGGTTGG CAGCGATATG TGAAAAAATT CAGAATTTAT 1320
GTTGTCTAAT TACAAAAAGC AACTTCTAGA ATCTTTAAAA ATAAAGGACG TTGTCATTAG 1380
TTCTTCTGGT TTGTATTATT CTAAAACCTT CCAAATCTTC AAATTTACTT TATTTTAAAA 1440
TGATAAAATG AAGTTGTCAT TTTATAAACC TTTTAAAAAG ATATATATAT ATGTTTTTCT 1500
AATGTGTAA AGTTCATTGG AACAGAAAGA AATGGATTTA TCTGCTCTTC GCGTTGAAGA 1560
AGTACAAAAT GTCATTAATG CTATGCAGAA AATCTTAGAG TGTCCCATCT GGTAAGTCAG 1620
CACAAAGAGTG TATTAATTTG GGATTCTAT GATTATCTCC TATGCAAATG AACAGAATTG 1680
ACCTTACATA CTAGGGAAGA AAAGACATGT CTAGTAAGAT TAGGCTATTG TAATTGCTGA 1740
TTTTCTTAAC TGAAGAACTT TAAAAATATA GAAAATGATT CCTTGTTCTC CATCCACTCT 1800
GCCTCTCCCA CTCCTCTCCT TTTCAACACA ATCCTGTGGT CCGGGAAGA CAGGGCTCTG 1860
TCTTGATTGG TTCTGCACTG GGCAGGATCT GTTAGATACT GCATTTGCTT TCTCCAGCTC 1920
TAAA 1924

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 631 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

AAATGCTGAT GATAGTATAG AGTATTGAAG GGATCAATAT AATTCTGTTT TGATATCTGA 60

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AAGCTCACTG AAGGTAAGGA TCGTATTCTC TGCTGTATTC TCAGTTCCTG ACACAGCAGA 120
CATTTAATAA ATATTGAACG AACTTGAGGC CTTATGTTGA CTCAGTCATA ACAGCTCAAA 180
GTTGAACTTA TTCACTAAGA ATAGCTTTAT TTTTAAATAA ATTATTGAGC CTCATTTATT 240
TTCTTTTCT CCCCCCCTA CCCTGCTAGT CTGGAGTTGA TCAAGGAACC TGTCTCCACA 300
AAGTGTGACC ACATATTTTG CAAGTAAGTT TGAATGTGTT ATGTGGCTCC ATTATTAGCT 360
TTTGTTTTTG TCCTTCATAA CCCAGGAAAC ACCTAACTTT ATAGAAGCTT TACTTCTTC 420
AATTAAGTGA GAACGAAAAT CCAACTCCAT TTCATTCTTT CTCAGAGAGT ATATAGTTAT 480
CAAAAGTTGG TTGTAATCAT AGTTCCTGGT AAAGTTTTGA CATATATTAT CTTTTTTTTT 540
TTTTGAGACA AGTCTCGCTC TGTCGCCCAG GCTGGAGTGC AGTGGCATGA GGCTTGCTCA 600
CTGCACCTCC GCCCCGAGT TCAGCGACTC T 631

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 481 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

TGAGATCTAG ACCACATGGT CAAAGAGATA GAATGTGAGC AATAAATGAA CCTTAAATTT 60
TTCAACAGCT ACTTTTTTTT TTTTTTTT AGACAGGGKC TTACTCTGTT GTCCCAGCTG 120
GAGTACAGWG TGCGATCATG AGGCTTACTG TTGCTTGACT CCTAGGCTCA AGCGATCCTA 180
TCACCTCAGT CTCCAAGTAG CTGGACTGTA AGTGCACACC ACCATATCCA GCTAAATTTT 240
GTGTTTTCTG TAGAGACGGG GTTTCGCCAT GTTCCCAGG CTGGTCTTGA ACTTTGGGCT 300
TAACCCGTCT GCCCACCTAG GCATCCCAA GTGCTAGGAT TACAGGTGTG AGTCATCATG 360
CCTGGCCAGT ATTTAGTTA GCTCTGTCTT TTCAAGTCAT ATACAAGTTC ATTTCTTTT 420

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AAGTTTAGTT AACAACTTA TATCATGTAT TCTTTTCTAG CATAAAGAAA GATTCGAGGC 480
C 481

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 522 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

TGTGATCATA ACAGTAAGCC ATATGCATGT AAGTTCAGTT TTCATAGATC ATTGCTTATG 60
TAGTTTAGGT TTTTGCTTAT GCAGCATCCA AAAACAATTA GGAACTATT GCTTGTAATT 120
CACCTGCCAT TACTTTTAA ATGGCTCTTA AGGGCAGTTG TGAGATTATC TTTTCATGGC 180
TATTGCGCTT TTGAGTATTC TTTCTACAAA AGGAAGTAAA TTAAATTGTT CTTTCTTCT 240
TTATAATTTA TAGATTTTGC ATGCTGAAAC TTCTCAACCA GAAGAAAGGG CCTTCACAGT 300
GTCCTTTATG TAAGAATGAT ATAACCAAAA GGTATATAAT TTGGTAATGA TGCTAGGTTG 360
GAAGCAACCA CAGTAGGAAA AAGTAGAAAT TATTTAATAA CATAGCGTTC CTATAAAACC 420
ATTCATCAGA AAAATTATA AAAGAGTTTT TAGCACACAG TAAATTATTT CCAAAGTTAT 480
TTTCCTGAAA GTTTTATGGG CATCTGCCTT ATACAGGTAT TG 522

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 465 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

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(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

GGTAGGCTTA AATGAATGAC AAAAAGTTAC TAAATCACTG CCATCACACG GTTTATACAG	60
ATGTCAATGA TGTATTGATT ATAGAGGTTT TCTACTGTTG CTGCATCTTA TTTTATTG	120
TTTACATGTC TTTTCTTATT TTAGTGTCCT TAAAAGGTTG ATAATCACTT GCTGAGTGTG	180
TTTCTCAAAC AATTTAATTT CAGGAGCCTA CAAGAAAGTA CGAGATTAG TCAACTTGTT	240
GAAGAGCTAT TGAAAATCAT TTGTGCTTTT CAGCTTGACA CAGGTTTGA GTGTAAGTGT	300
TGAATATCCC AAGAATGACA CTCAAGTGCT GTCCATGAAA ACTCAGGAAG TTTGCACAAT	360
TACTTTCTAT GACGTGGTGA TAAGACCTTT TAGTCTAGGT TAATTTAGT TCTGTATCTG	420
TAATCTATTT TAAAAAATTA CTCCCACTGG TCTCACACCT TATTT	465

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 513 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

AAAAAATCAC AGGTAACCTT AATGCATTGT CTTAACACAA CAAAGAGCAT ACATAGGGTT	60
TCTCTTGGTT TCTTTGATTA TAATTCATAC ATTTTCTCT AACTGCAAAC ATAATGTTTT	120
CCCTTGATT TTACAGATGC AAACAGCTAT AATTTTGCAA AAAAGGAAAA TAACTCTCCT	180
GAACATCTAA AAGATGAAGT TTCTATCATC CAAAGTATGG GCTACAGAAA CCGTGCCAAA	240
AGACTTCTAC AGAGTGAACC CGAAAATCCT TCCTTGGTAA AACCATTGT TTTCTTCTTC	300

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TTCTTCTTCT TCTTTTCTTT TTTTTTCTT TTTTTTTTG AGATGGAGTC TTGCTCTGTG 360
GCCCAGGCTA GAAGCAGTCC TCCTGCCTTA GCCNCCTTAG TAGCTGGGAT TACAGGCACG 420
CGCACCATGC CAGGCTAATT TTTGTATTTT TAGTAGAGAC GGGGTTTCAT CATGTTGGCC 480
AGGCTGGTCT CGAACTCCTA ACCTCAGGTG ATC 513

(2) INFORMATION FOR SEQ ID NO:20:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 6769 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (iv) ANTI-SENSE: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

ATGATGGAGA TCTTAAAAAG TAATCATTCT GGGGCTGGGC GTAGTAGCTT GCACCTGTAA 60
TCCCAGCACT TCGGGAGGCT GAGGCAGGCA GATAATTTGA GGTGAGGAGT TTGAGACCAG 120
CCTGGCCAAC ATGGTGAAAC CCATCTCTAC TAAAAATACA AAAATTAGCT GGGTGTGGTG 180
GCACGTACCT GTAATCCAG CTA CTCTCGGA GCGGAGGCA CAAGAATTGC TTGAACCTAG 240
GACGCGGAGG TTGCAGCGAG CCAAGATCGC GCCACTGCAC TCCAGCCTGG GCCGTAGAGT 300
GAGACTCTGT CTCAAAAAAG AAAAAAAGT AATTGTTCTA GCTGGGCGCA GTGGCTCTTG 360
CCTGTAATCC CAGCACTTTG GGAGGCCAAG GCGGGTGGAT CTCGAGTCCT AGAGTTCAAG 420
ACCAGCCTAG GCAATGTGGT GAAACCCCAT CGCTACAAAA AATACAAAAA TTAGCCAGGC 480
ATGGTGGCGT GCGCATGTAG TCCCAGCTCC TTGGGAGGCT GAGGTGGGAG GATCACTTGA 540
ACCCAGGAGA CAGAGGTTGC AGTGAACCGA GATCACGCCA CCACGCTCCA GCCTGGGCAA 600
CAGAACAAGA CTCTGTCTAA AAAAATACAA ATAAAATAAA AGTAGTTCTC ACAGTACCAG 660
CATTCATTTT TCAAAAGATA TAGAGCTAAA AAGGAAGGAA AAAAAAGTA ATGTTGGGCT 720
TTTAAATACT CGTTCCTATA CTAAATGTTT TTAGGAGTGC TGGGGTTTTA TTGTCATCAT 780

TTATCCTTTT TAAAAATGTT ATTGGCCAGG CACGGTGGCT CATGGCTGTA ATCCCAGCAC	840
TTTGGGAGGC CGAGGCAGGC AGATCACCTG AGGTCAGGAG TGTGAGACCA GCCTGGCCAA	900
CATGGCGAAA CCTGTCTCTA CTAAAAATAC AAAAATTAAC TAGGCGTGGT GGTGTACGCC	960
TGTAGTCCCA GCTACTCGGG AGGCTGAGGC AGGAGAATCA ACTGAACCAG GGAGGTGGAG	1020
GTTGCAGTGT GCCGAGATCA CGCCACTGCA CTCTAGCCTG GCAACAGAGC AAGATTCTGT	1080
CTCAAAAAAA AAAACATAT ATACACATAT ATCCCAAAGT GCTGGGATTA CATATATATA	1140
TATATATATA TATTATATAT ATATATATAT ATATATGTGA TATATATGTG ATATATATAT	1200
AACATATATA TATGTAATAT ATATGTGATA TATATATAAT ATATATATGT AATATATATG	1260
TGATATATAT ATATACACAC ACACACACAT ATATATGTAT GTGTGTGTAC ACACACACAC	1320
ACAAATTAGC CAGGCATAGT TGCACACGCT TGGTAGACCC AGCTACTCAG GAGGCTGAGG	1380
GAGGAGAATC TCTTGAACCT AGGAGGCGGA GGTTCAGTG AGCTGAGATT GCGCCACTGC	1440
ACTCCAGCCT GGGTGACAGA GCAGGACTCT GTACACCCCC CAAAACAAAA AAAAAAGTTA	1500
TCAGATGTGA TTGGAATGTA TATCAAGTAT CAGCTTCAAA ATATGCTATA TTAATACTTC	1560
AAAAATTACA CAAATAATAC ATAATCAGGT TTGAAAAATT TAAGACAACM SAARAAAAAA	1620
WYCMATCAC AMATATCCCA CACATTTTAT TATTMCTMCT MCWATTATTT TGWAGAGMCT	1680
GGGTCTCACY CYKTTGCTWA TGCTGGTCTT TGAACYCCYK GCCYCAARCA RTCCTSCTCC	1740
ABCCTCCCAA RGTGCTGGGG ATWATAGGCA TGARCTAACC GCACCCAGCC CCAGACATTT	1800
TAGTGTGTAA ATTCCTGGGC ATTTTTCCTCA GGCATCATAC ATGTTAGCTG ACTGATGATG	1860
GTCAATTTAT TTTGTCCATG GTGTCAAGTT TCTCTTCAGG AGGAAAAGCA CAGAACTGGC	1920
CAACAATTGC TTGACTGTTC TTTACCATAC TGTTTAGCAG GAAACCAGTC TCAGTGTCCA	1980
ACTCTCTAAC CTTGGAAGTGT TGAGAACTCT GAGGACAAAG CAGCGGATAC AACCTCAAAA	2040
GACGTCTGTC TACATTGAAT TGGGTAAGGG TCTCAGGTTT TTTAAGTATT TAATAATAAT	2100
TGCTGGATTG CTTATCTTAT AGTTTTCGCA AAAATCTTGG TCATAATTG TATTTGTGGT	2160
AGGCAGCTTT GGGAAAGTGAA TTTTATGAGC CCTATGGTGA GTTATAAAAA ATGTAAAAGA	2220
CGCAGTCCC ACCTTGAAGA ATCTTACTTT AAAAAGGGAG CAAAAGAGGC CAGGCATGGT	2280
GGCTCACACC TGTAATCCCA GCACTTTGGG AGGCCAAAGT GGGTGGATCA CCTGAGGTG	2340
GGAGTTCGAG ACCAGCCTAG CCAACATGGA GAAACTCTGT CTGTACCAAA AAATAAAAAA	2400

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TTAGCCAGGT GTGGTGGCAC ATAAGTGTAA TCCCAGCTAC TCGGGAGGCT GAGGCAGGAG	2460
AATCACTTGA ACCCGGGAGG TGGAGGTTGC GGTGAACCGA GATCGCACCA TTGCACTCCA	2520
GCCTGGGCAA AAATAGCGAA ACTCCATCTA AAAAAAAAAA AGAGAGCAAA AGAAAGAMTM	2580
TCTGGTTTTA AMTMTGTGTA AATATGTTTT TGGAAAGATG GAGAGTAGCA ATAAGAAAAA	2640
ACATGATGGA TTGCTACAGT ATTTAGTTCC AAGATAAATT GTAGTAGATG AGGAAGCCTT	2700
TTAAGAAGAG CTGAATTGCC AGGCGCAGTG GCTCACGCCT GTAATCCCAG CACTTTGGGA	2760
GGCCGAGGTG GGCGGATCAC CTGAGGTCGG GAGTTCAAGA CCAGCCTGAC CAACATGGAG	2820
AAACCCCATC TCTACTAAAA AAAAAAAAAA AAAAATTAGC CGGGGTGGTG GCTTATGCCT	2880
GTAATCCCAG CTAAGTACGA GGCTGAGGCA GGAGAATCGC TTGAACCCAG GAAGCAGAGG	2940
TTGCAGTGAG CCAAGATCGC ACCATTGCAC TCCAGCCTAG GCAACAAGAG TGAAACTCCA	3000
TCTCAAAAAA AAAAAAAAAA AGCTGAATCT TGGCTGGGCA GGATGGCTCG TGCCTGTAAT	3060
CCTAACGCTT TGGAAGACCG AGGCAGAAGG ATTGGTTGAG TCCACGAGTT TAAGACCAGC	3120
CTGGCCAACA TAGGGGAACC CTGTCTCTAT TTTTAAAATA ATAATACATT TTTGGCCGGT	3180
GCGGTGGCTC ATGCCTGTAA TCCCAATACT TTGGGAGGCT GAGGCAGGTA GATCACCTGA	3240
GGTCAGAGTT CGAGACCAGC CTGGATAACC TGGTGAAACC CCTCTTTACT AAAAATACAA	3300
AAAAAAAAAA AAATTAGCTG GGTGTGGTAG CACATGCTTG TAATCCCAGC TACTTGGGAG	3360
GCTGAGGCAG GAGAATCGCT TGAACCAGGG AGGCGGAGGT TACAATGAGC CAACACTACA	3420
CCACTGCACT CCAGCCTGGG CAATAGAGTG AGACTGCATC TCAAAAAAAT AATAATTTTT	3480
AAAAATAATA AATTTTTTTA AGCTTATAAA AAGAAAAGTT GAGGCCAGCA TAGTAGCTCA	3540
CATCTGTAAT CTCAGCAGTG GCAGAGGATT GCTTGAAGCC AGGAGTTTGA GACCAGCCTG	3600
GGCAACATAG CAAGACCTCA TCTCTACAAA AAAATTTCTT TTTTAAATTA GCTGGGTGTG	3660
GTGGTGTGCA TCTGTAGTCC CAGCTACTCA GGAGGCAGAG GTGAGTGGAT ACATTGAACC	3720
CAGGAGTTTG AGGCTGTAGT GAGCTATGAT CATGCCACTG CACTCCAACC TGGGTGACAG	3780
AGCAAGACCT CCAAAAAAAA AAAAAAAGA GCTGCTGAGC TCAGAATTCA AACTGGGCTC	3840
TCAAATTGGA TTTCTTTTGA GAATATATTT ATAATTAAAA AGGATAGCCA TCTTTTGAGC	3900
TCCCAGGCAC CACCATCTAT TTATCATAAC ACTTACTGTT TTCCCCCTT ATGATCATAA	3960
ATTCTAGAC AACAGGCATT GTAAAAATAG TTATAGTAGT TGATATTTAG GAGCACTTAA	4020
CTATATTCCA GGCACATTG TGCTTTTCTT GTATAACTCA TTAGATGCTT GTCAGACCTC	4080

TGAGATTGTT CCTATTATAC TTATTTTACA GATGAGAAAA TTAAGGCACA GAGAAGTTAT	4140
GAAATTTTTC CAAGGTATTA AACCTAGTAA GTGGCTGAGC CATGATTCAA ACCTAGGAAG	4200
TTAGATGTCA GAGCCTGTGC TTTTTTTTTG TTTTGTGTTT TGTTTTTCAGT AGAAACGGGG	4260
GTCTCACTTT GTTGGCCAGG CTGGTCTTGA ACTCCTAACC TCAAATAATC CACCCATCTC	4320
GGCCTCCTCA AGTGCTGGGA TTACAGGTGA GAGCCACTGT GCCTGGCGAA GCCCATGCCT	4380
TTAACCACCTT CTCTGTATTA CATACTAGCT TAACTAGCAT TGTACCTGCC ACAGTAGATG	4440
CTCAGTAAAT ATTTCTAGTT GAATATCTGT TTTTCAACAA GTACATTTTT TTAACCCTTT	4500
TAATTAAGAA AACTTTTATT GATTTATTTT TTGGGGGGAA ATTTTTTAGG ATCTGATTCT	4560
TCTGAAGATA CCGTTAATAA GGCAACTTAT TGCAGGTGAG TCAAAGAGAA CCTTTGTCTA	4620
TGAAGCTGGT ATTTTCCTAT TTAGTTAATA TTAAGGATTG ATGTTTCTCT CTTTTTAAAA	4680
ATATTTTAAC TTTTATTTTA GGTTCAGGGA TGTATGTGCA GTTTGTTATA TAGGTAAACA	4740
CACGACTTGG GATTTGGTGT ATAGATTTTT TTCATCATCC GGGTACTAAG CATACCCCAC	4800
AGTTTTTTGT TTGCTTTCTT TCTGAATTC TCCCTCTCC CACCTTCCTC CCTCAAGTAG	4860
GCTGGTGTTT CTCCAGACTA GAATCATGGT ATTGGAAGAA ACCTTAGAGA TCATCTAGTT	4920
TAGTTCTCTC ATTTTATAGT GGAGGAAATA CCCTTTTTGT TTGTTGGATT TAGTTATTAG	4980
CACTGTCCAA AGGAATTTAG GATAACAGTA GAACTCTGCA CATGCTTGCT TCTAGCAGAT	5040
TGTTCTCTAA GTTCCTCATA TACAGTAATA TTGACACAGC AGTAATTGTG ACTGATGAAA	5100
ATGTTCAAGG ACTTCATTTT CAACTCTTTC TTTCCTCTGT TCCTTATTTT CACATATCTC	5160
TCAAGCTTTG TCTGTATGTT ATATAATAAA CTACAAGCAA CCCCAACTAT GTTACCTACC	5220
TTCCTTAGGA ATTATTGCTT GACCCAGGTT TTTTTTTTTT TTTTTTTGGA GACGGGGTCT	5280
TGCCCTGTTG CCAGGATGGA GTGTAGTGGC GCCATCTCGG CTCACTGCAA TCTCCAATC	5340
CCTGGTTCAA GCGATTCTCC TGTCTCAATC TCACGAGTAG CTGGGACTAC AGGTATACAC	5400
CACCACGCCC GGTTAATTGA CCATTCCATT TCTTCTTTC TCTCTTTTTT TTTTTTTTTT	5460
TTGAGACAGA GTCTTGCTCT GTTGCCAGG CTGGAGTACA GAGGTGTGAT CTCACCTCTC	5520
CGCAACGTCT GCCTCCCAGG TTGAAGCCAT ACTCCTGCCT CAGCCTCTCT AGTAGCTGGG	5580
ACTACAGGCG CGCGCCACCA CACCCGGCTA ATTTTTGTAT TTTTAGTAGA GATGGGGTTT	5640
CACCATGTTG GCCAGGCTGG TCTTGAATC ATGACCTCAA GTGGTCCACC CGCCTCAGCC	5700

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TCCCAAAGTG CTGGAATTAC AGGCTTGAGC CACCGTGCCC AGCAACCATT TCATTCAAC	5760
TAGAAGTTTC TAAAGGAGAG AGCAGCTTTC ACTAACTAAA TAAGATTGGT CAGCTTTCTG	5820
TAATCGAAAG AGCTAAAATG TTTGATCTTG GTCATTGAC AGTTCTGCAT ACATGTAAC	5880
AGTGTTTCTT ATTAGGACTC TGTCTTTTCC CTATAGTGTG GGAGATCAAG AATTGTTACA	5940
AATCACCCCT CAAGGAACCA GGGATGAAAT CAGTTTGGAT TCTGCAAAAA AGGTAATGG	6000
CAAAGTTTGC CAACTTAACA GGCAGTGAAG AGAGAGTGGG TAGATACAGT ACTGTAATTA	6060
GATTATTCTG AAGACCATTT GGGACCTTTA CAACCCACAA AATCTCTTGG CAGAGTTAGA	6120
GATCATTCT CTGTCAAATG TCGTGGTATG GTCTGATAGA TTTAAATGGT ACTAGACTAA	6180
TGTACCTATA ATAAGACCTT CTTGTAACTG ATTGTTGCCC TTTCGCTTTT TTTTTGTTT	6240
GTTTGTTTGT TTTTTTTTGA GATGGGGTCT CACTCTGTTG CCCAGGCTGG AGTGCAGTGA	6300
TGCAATCTTG GCTCACTGCA ACCTCCACCT CCAAAGGCTC AAGCTATCCT CCCACTTCAG	6360
CCTCCTGAGT AGCTGGGACT ACAGGCGCAT GCCACCACAC CCGGTTAATT TTTGTGGTT	6420
TTATAGAGAT GGGGTTTCAC CATGTTACCG AGGCTGGTCT CAAACTCCTG GACTCAAGCA	6480
GTCTGCCCAC TTCAGCCTCC CAAAGTGCTG CAGTTACAGG CTTGAGCCAC TGTGCCTGGC	6540
CTGCCCTTTA CTTTAAATTG GTGTATTTGT GTTTCATCTT TTACCTACTG GTTTTTAAAT	6600
ATAGGGAGTG GTAAGTCTGT AGATAGAACA GAGTATTAAG TAGACTTAAT GGCCAGTAAT	6660
CTTTAGAGTA CATCAGAACC AGTTTCTGA TGGCCAATCT GCTTTTAATT CACTCTTAGA	6720
CGTTAGAGAA ATAGGTGTGG TTTCTGCATA GGGAAAATTC TGAAATTAA	6769

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 4249 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

GATCCTAAGT GGAAATAATC TAGGTAAATA GGAATTAAAT GAAAGAGTAT GAGCTACATC	60
TTCAGTATAC TTGGTAGTTT ATGAGGTTAG TTTCTCTAAT ATAGCCAGTT GGTGATTTC	120
CACCTCCAAG GTGTATGAAG TATGTATTTT TTTAATGACA ATTCAGTTT TGAGTACCTT	180
GTTATTTTGT TATATTTTCA GCTGCTTGTG AATTTTCTGA GACGGATGTA ACAAATACTG	240
AACATCATCA ACCCAGTAAT AATGATTTGA ACACCACTGA GAAGCGTGCA GCTGAGAGGC	300
ATCCAGAAAA GTATCAGGGT AGTTCTGTTT CAAACTTGCA TGTGGAGCCA TGTGGCACAA	360
ATACTCATGC CAGCTCATTA CAGCATGAGA ACAGCAGTTT ATTACTCACT AAAGACAGAA	420
TGAATGTAGA AAAGGCTGAA TTCTGTAATA AAAGCAAACA GCCTGGCTTA GCAAGGAGCC	480
AACATAACAG ATGGGCTGGA AGTAAGGAAA CATGTAATGA TAGGCGGACT CCCAGCACAG	540
AAAAAAGGT AGATCTGAAT GCTGATCCCC TGTGTGAGAG AAAAGAATGG AATAAGCAGA	600
AACTGCCATG CTCAGAGAAT CCTAGAGATA CTGAAGATGT TCCTTGATA AACTAAATA	660
GCAGCATTCA GAAAGTTAAT GAGTGGTTTT CCAGAAGTGA TGAAGTGTTA GGTCTGATG	720
ACTCACATGA TGGGGAGTCT GAATCAAATG CCAAAGTAGC TGATGTATTG GACGTTCTAA	780
ATGAGGTAGA TGAATATTCT GGTCTTTCAG AGAAAATAGA CTTACTGGCC AGTGATCCTC	840
ATGAGGCTTT AATATGTAAA AGTGAAAGAG TTCACTCCAA ATCAGTAGAG AGTAATATTG	900
AAGGCCAAAT ATTTGGGAAA ACCTATCGGA AGAAGGCAAG CCTCCCCAAC TTAAGCCATG	960
TAAGTAAAA TCTAATTATA GGAGCATTTG TTAGTGAGCC ACAGATAATA CAAGAGCGTC	1020
CCCTCACAAA TAAATTAAAG CGTAAAAGGA GACCTACATC AGGCCTTCAT CCTGAGGATT	1080
TTATCAAGAA AGCAGATTTG GCAGTTCAAA AGACTCCTGA AATGATAAAT CAGGGAAC TA	1140
ACCAAACGGA GCAGAATGGT CAAGTGATGA ATATTACTAA TAGTGGTCAT GAGAATAAAA	1200
CAAAGGTGA TTCTATTAG AATGAGAAAA ATCTAACCC AATAGAATCA CTCGAAAAAG	1260
AATCTGCTTT CAAAACGAAA GCTGAACCTA TAAGCAGCAG TATAAGCAAT ATGGAAC TCG	1320
AATTAAATAT CCACAATTCA AAAGCACCTA AAAAGAATAG GCTGAGGAGG AAGTCTTCTA	1380
CCAGGCATAT TCATGCGCTT GAACTAGTAG TCAGTAGAAA TCTAAGCCCA CTAATTGTA	1440
CTGAATTGCA AATTGATAGT TGTCTAGCA GTGAAGAGAT AAAGAAAAAA AAGTACAACC	1500
AAATGCCAGT CAGGCACAGC AGAAACCTAC AACTCATGGA AGGTAAAGAA CCTGCAACTG	1560
GAGCCAAGAA GAGTAACAAG CCAATGAAC AGACAAGTAA AAGACATGAC AGCGATACTT	1620

TCCCAGAGCT GAAGTTAACA AATGCACCTG GTTCTTTTAC TAAGTGTTCA AATACCAGTG 1680
AACTTAAAGA ATTTGTCAAT CCTAGCCTTC CAAGAGAAGA AAAAGAAGAG AACTAGAAAC 1740
AGTTAAAGTG TCTAATAATG CTGAAGACCC CAAAGATCTC ATGTTAAGTG GAGAAAGGGT 1800
TTTGCAAAC TAAAGATCTG TAGAGAGTAG CAGTATTTCA TTGGTACCTG GTACTGATTA 1860
TGGCACTCAG GAAAGTATCT CGTTACTGGA AGTTAGCACT CTAGGGAAGG CAAAAACAGA 1920
ACCAAATAAA TGTGTGAGTC AGTGTGCAGC ATTTGAAAAC CCCAAGGGAC TAATTCATGG 1980
TTGTTCCAAA GATAATAGAA ATGACACAGA AGGCTTTAAG TATCCATTGG GACATGAAGT 2040
TAACCACAGT CGGGAAACAA GCATAGAAAT GGAAGAAAGT GAACTTGATG CTCAGTATTT 2100
GCAGAATACA TTCAAGGTTT CAAAGCGCCA GTCATTTGCT CCGTTTTCAA ATCCAGGAAA 2160
TGCAGAAGAG GAATGTGCAA CATTCTCTGC CCACTCTGGG TCCTTAAAGA AACAAAGTCC 2220
AAAAGTCACT TTTGAATGTG AACAAAAGGA AGAAAATCAA GGAAAGAATG AGTCTAATAT 2280
CAAGCCTGTA CAGACAGTTA ATATCACTGC AGGCTTTCCT GTGGTTGGTC AGAAAGATAA 2340
GCCAGTTGAT AATGCCAAAT GTAGTATCAA AGGAGGCTCT AGGTTTGTGC TATCATCTCA 2400
GTTCAGAGGC AACGAACTG GACTCATTAC TCCAAATAAA CATGGACTTT TACAAAACCC 2460
ATATCGTATA CCACCACTTT TTCCCATCAA GTCATTTGTT AAACTAAAT GTAAGAAAAA 2520
TCTGCTAGAG GAAAACCTTG AGGAACATTC AATGTCACCT GAAAGAGAAA TGGGAAATGA 2580
GAACATTCCA AGTACAGTGA GCACAATTAG CCGTAATAAC ATTAGAGAAA ATGTTTTTAA 2640
AGAAGCCAGC TCAAGCAATA TTAATGAAGT AGGTTCCAGT ACTAATGAAG TGGGCTCCAG 2700
TATTAATGAA ATAGGTTCCA GTGATGAAAA CATTCAAGCA GAACTAGGTA GAAACAGAGG 2760
GCCAAAATTG AATGCTATGC TTAGATTAGG GGTTTTGCAA CCTGAGGTCT ATAAACAAAG 2820
TCTTCCTGGA AGTAATTGTA AGCATCCTGA AATAAAAAAG CAAGAATATG AAGAAGTAGT 2880
TCAGACTGTT AATACAGATT TCTCTCCATA TCTGATTTCA GATAACTTAG AACAGCCTAT 2940
GGGAAGTAGT CATGCATCTC AGGTTTGTTT TGAGACACCT GATGACCTGT TAGATGATGG 3000
TGAAATAAAG GAAGATACTA GTTTTGCTGA AAATGACATT AAGGAAAGTT CTGCTGTTTT 3060
TAGCAAAGC GTCCAGAAAG GAGAGCTTAG CAGGAGTCCT AGCCCTTTCA CCCATACACA 3120
TTTGGCTCAG GGTTACCGAA GAGGGGCCAA GAAATTAGAG TCCTCAGAAG AGAACTTATC 3180
TAGTGAGGAT GAAGAGCTTC CCTGCTTCCA ACACCTTGTTA TTTGGTAAAG TAAACAATAT 3240

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ACCTTCTCAG TCTACTAGGC ATAGCACCGT TGCTACCGAG TGTCTGTCTA AGAACACAGA	3300
GGAGAATTTA TTATCATTGA AGAATAGCTT AAATGACTGC AGTAACCAGG TAATATTGGC	3360
AAAGGCATCT CAGGAACATC ACCTTAGTGA GGAAACAAAA TGTTCGTCTA GCTTGTTTTT	3420
TTCACAGTGC AGTGAATTGG AAGACTTGAC TGCAAATACA AACACCCAGG ATCCTTTCTT	3480
GATTGGTTCT TCCAAACAAA TGAGGCATCA GTCTGAAAGC CAGGGAGTTG GTCTGAGTGA	3540
CAAGGAATTG GTTTCAGATG ATGAAGAAAG AGGAACGGGC TTGGAAGAAA ATAATCAAGA	3600
AGAGCAAAGC ATGGATTCAA ACTTAGGTAT TGGAACCAGG TTTTGTGTT TGCCCCAGTC	3660
TATTTATAGA AGTGAGCTAA ATGTTTATGC TTTTGGGGAG CACATTTTAC AAATTTCCAA	3720
GTATAGTTAA AGGAACTGCT TCTTAACTT GAAACATGTT CCTCCTAAGG TGCTTTTCAT	3780
AGAAAAAGT CCTTCACACA GCTAGGACGT CATCTTTGAC TGAATGAGCT TTAACATCCT	3840
AATTACTGGT GGACTTACTT CTGGTTTCAT TTTATAAAGC AAATCCCGGT GTCCCAAAGC	3900
AAGGAATTTA ATCATTTTGT GTGACATGAA AGTAAATCCA GTCCTGCCAA TGAGAAGAAA	3960
AAGACACAGC AAGTTGCAGC GTTTATAGTC TGCTTTTACA TCTGAACCTC TGTTTTTGT	4020
ATTTAAGGTG AAGCAGCATC TGGGTGTGAG AGTGAAACAA GCGTCTCTGA AGACTGCTCA	4080
GGGCTATCCT CTCAGAGTGA CATTTTAACC ACTCAGGTAA AAAGCGTGTG TGTGTGTGCA	4140
CATGCGTGTG TGTGGTGTCC TTTGCATTCA GTAGTATGTA TCCCACATTC TTAGGTTTGC	4200
TGACATCATC TCTTTGAATT AATGGCACAA TTGTTTGTGG TTCATTGTC	4249

(2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 710 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

NGNGAATGTA ATCCTAATAT TTCNCNCCNA CTTAAAAGAA TACCACTCCA ANGGCATCNC	60
AATACATCAA TCAATTGGGG AATTGGGATT TTCCCTCNCT AACATCANTG GAATAATTTT	120
ATGGCATTAA TTGCATGAAT GTGGTTAGAT TAAAAGGTGT TCATGCTAGA ACTTGTTAGTT	180
CCATACTAGG TGATTTCAAT TCCTGTGCTA AAATTAATTT GTATGATATA TTNTCATTTA	240
ATGGAAAGCT TCTCAAAGTA TTTCAITTTT TTGGTACCAT TTATCGTTTT TGAAGCAGAG	300
GGATACCATG CAACATAACC TGATAAAGCT CCAGCAGGAA ATGGCTGAAC TAGAAGCTGT	360
GTTAGAACAG CATGGGAGCC AGCCTTCTAA CAGCTACCTT TCCATCATAA GTGACTCTTC	420
TGCCCTTGAG GACCTGCGAA ATCCAGAACA AAGCACATCA GAAAAAGGTG TGTATTGTTG	480
GCCAAACACT GATATCTTAA GCAAAATTCT TTCCTTCCCC TTTATCTCCT TCTGAAGAGT	540
AAGGACCTAG CTCCAACATT TTATGATCCT TGCTCAGCAC ATGGGTAATT ATGGAGCCTT	600
GGTTCTTGTC CCTGCTCACA ACTAATATAC CAGTCAGAGG GACCCAAGGC AGTCATTCAT	660
GTTGTCATCT GAGATACCTA CAACAAGTAG ATGCTATGGG GAGCCCATGG	710

(2) INFORMATION FOR SEQ ID NO:23:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 473 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (iv) ANTI-SENSE: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

CCATTGGTGC TAGCATCTGT CTGTTGCATT GCTTGTGTTT ATAAAATTCT GCCTGATATA	60
CTTGTTAAAA ACCAATTTGT GTATCATAGA TTGATGCTTT TGAAAAAAT CAGTATTCTA	120
ACCTGAATTA TCACTATCAG AACAAAGCAG TAAAGTAGAT TTGTTTTCTC ATTCCATTTA	180
AAGCAGTATT AACTTCACAG AAAAGTAGTG AATACCCTAT AAGCCAGAAT CCAGAAGGCC	240

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TTTCTGCTGA CAAGTTTGAG GTGTCTGCAG ATAGTTCTAC CAGTAAAAAT AAAGAACCAG	300
GAGTGGAAG GTAAGAAACA TCAATGTAAA GATGCTGTGG TATCTGACAT CTTTATTTAT	360
ATTGAACTCT GATTGTTAAT TTTTTCACC ATACTTTCTC CAGTTTTTTT GCATACAGGC	420
ATTTATACAC TTTTATTGCT CTAGGATACT TCTTTTGTTC AATCCTATAT AGG	473

(2) INFORMATION FOR SEQ ID NO:24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 421 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

GGATAAGNTC AAGAGATATT TTGATAGGTG ATGCAGTGAT NAATTGNGAA AATTNCTGC	60
CTGCTTTTAA TCTTCCCCCG TCTTTCTTC CTNCCTCCCT CCCTTCTNC CTCCCGTCCT	120
TNCCTTTCCT TCCCTCCCT TCCNCCTTCT TTCNTCTNT CTTTCCTTTC TTCTCTGTCT	180
ACCTTCTTTT CCTTCTCCC TTCTTTTCT TTTCTTCTT TCCTTCTCTT TTCTTCTCTT	240
TCTTCTCTT CCTTCTTTC TTGACAGAGT CTGCTCTGT CACTCAGGCT GGAGTGCAGT	300
GGCGTGATCT CGNCTCACTG CAACCTCTGT CTCCAGGTT CAAGCAATTT TCCTGCCTCA	360
GCCTCCCGAG TAGCTGAGAT TACAGGCGCC AGCCACCACA CCCAGCTACT GACCTGCTTT	420
T	421

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 997 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

AAACAGCTGG GAGATATGGT GCCTCAGACC AACCCCATGT TATATGTCAA CCCTGACATA	60
TTGGCAGGCA ACATGAATCC AGACTTCTAG GCTGTCATGC GGGCTCTTTT TTGCCAGTCA	120
TTTCTGATCT CTCTGACATG AGCTGTTTCA TTTATGCTTT GGCTGCCCAG CAAGTATGAT	180
TTGTCCTTTC ACAATTGGTG GCGATGGTTT TCTCCTTCCA TTTATCTTTC TAGGTCATCC	240
CCTTCTAAAT GCCCATCATT AGATGATAGG TGGTACATGC ACAGTTGCTC TGGGAGTCTT	300
CAGAATAGAA ACTACCCATC TCAAGAGGAG CTCATTAAGG TTGTTGATGT GGAGGAGCAA	360
CAGCTGGAAG AGTCTGGGCC ACACGATTG ACGGAAACAT CTTACTTGCC AAGGCAAGAT	420
CTAGGTAATA TTTCATCTGC TGTATTGGAA CAAACACTYT GATTTTACTC TGAATCCTAC	480
ATAAAGATAT TCTGGTTAAC CAACTTTTAG ATGTACTAGT CTATCATGGA CACTTTTGTT	540
ATACTTAATT AAGCCCACTT TAGAAAAATA GCTCAAGTGT TAATCAAGGT TTAATTGAAA	600
ATTATTGAAA CTGTTAATCC ATCTATATTT TAATTAATGG TTAACTAAT GATTTTGAGG	660
ATGWGGGAGT CKTGGTGTAC TCTAMATGTA TTATTTTCAAG CCAGGCATAG TGGCTCACGC	720
CTGGTAATCC CAGTAYYCMR GAGCCCAGG CAGGTGGAGC CAGCTGAGGT CAGGAGTTCA	780
AGACCTGTCT TGGCCAACAT GGGNGAAACC CTGTCTTCTT CTTAAAAAAN ACAAAAAAAA	840
TTAACTGGGT TGTGCTTAGG TGNATGCCCC GNATCCTAGT TMTTCTTGNG GGTTGAGGGA	900
GGAGATCACN TTGGACCCCG GAGGGGNGGG TGGGGGNGAG CAGGNCAAAA CACNGACCCA	960
GCTGGGGTGG AAGGGAAGCC CACTCNAAAA AANNTTN	997

(2) INFORMATION FOR SEQ ID NO:26:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 639 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

TTTTTAGGAA ACAAGCTACT TTGGATTTCC ACCAACACCT GTATTCATGT ACCCATTTTT	60
CTCTTAACCT AACTTTATTG GTCTTTTAA TTCTTAACAG AGACCAGAAC TTTGTAATTC	120
AACATTCATC GTTGTGTAAA TTAACTTCT CCCATTCCTT TCAGAGGGAA CCCCTTACCT	180
GGAATCTGGA ATCAGCCTCT TCTCTGATGA CCCTGAATCT GATCCTTCTG AAGACAGAGC	240
CCCAGAGTCA GCTCGTGTG GCAACATACC ATCTTCAACC TCTGCATTGA AAGTTCCCCA	300
ATTGAAAGTT GCAGAACTG CCCAGAGTCC AGCTGCTGCT CATACTACTG ATACTGCTGG	360
GTATAATGCA ATGGAAGAAA GTGTGAGCAG GGAGAAGCCA GAATTGACAG CTTCAACAGA	420
AAGGGTCAAC AAAAGAATGT CCATGGTGGT GTCTGGCCTG ACCCCAGAAG AATTTGTGAG	480
TGTATCCATA TGTATCTCCC TAATGACTAA GACTTAACAA CATTCTGGAA AGAGTTTTAT	540
GTAGGTATTG TCAATTAATA ACCTAGAGGA AGAAATCTAG AAAACAATCA CAGTTCTGTG	600
TAATTTAATT TCGATTACTA ATTTCTGAAA ATTTAGAAY	639

(2) INFORMATION FOR SEQ ID NO:27:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 922 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27:

NCCCNCCCC CNAATCTGAA ATGGGGGTAA CCCCCCCCCA ACCGANACNT GGGTNGCNTA	60
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GAGANTTTAA TGGCCCN TTC TGAGGNACAN AAGCTTAAGC CAGGNGACGT GGANCNATGN	120
GTGTGTTTNTT GTTTGGTTAC CTCCAGCCTG GGTGACAGAG CAAGACTCTG TCTAAAAAAA	180
AAAAAAAAAA AAATCGACTT TAAATAGTTC CAGGACACGT GTAGAACGTG CAGGATTGCT	240
ACGTAGGTAA ACATATGCCA TGGTGGGATA ACTAGTATTC TGAGCTGTGT GCTAGAGGTA	300
ACTCATGATA ATGGAATATT TGATTTAATT TCAGATGCTC GTGTACAAGT TTGCCAGAAA	360
ACACCACATC ACTTTAACTA ATCTAATTAC TGAAGAGACT ACTCATGTTG TTATGAAAAC	420
AGGTATACCA AGAACCTTTA CAGAATACCT TGCATCTGCT GCATAAAACC ACATGAGGCG	480
AGGCACGGTG GCGCATGCCT GTAATCGCAG CACTTTGGGA GGCCGAGGCG GGCAGATCAC	540
GAGATTAGGA GATCGAGACC ATCCTGGCCA GCATGGTGAA ACCCCGTCTC TACTANNAAA	600
TGGNAAAATT ANCTGGGTGT GGTGCGGTGC NCCTGTAGTC CCAGCTACTC GTGAGGCTGA	660
GGCAGGAGAA TCACTTGAAC CGGGGAAATG GAGGTTTCAG TGAGCAGAGA TCATNCCCCT	720
NCATTCCAGC CTGGCGACAG AGCAAGGCTC CGTCNCCNAA AAAATAAAAA AAAACGTGAA	780
CAAATAAGAA TATTTGTTGA GCATAGCATG GATGATAGTC TTCTAATAGT CAATCAATTA	840
CTTTATGAAA GACAAATAAT AGTTTGCTG CTTCCTTACC TCCTTTTGTT TTGGGTAAAG	900
ATTGGAGTG TGGGCCAGGC AC	922

(2) INFORMATION FOR SEQ ID NO:28:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 867 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (iv) ANTI-SENSE: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:28:

GATCTATAGC TAGCCTTGGC GTCTAGAAGA TGGGTGTTGA GAAGAGGGAG TGGAAAGATA	60
TTTCCTCTGG TCTTAACTTC ATATCAGCCT CCCCTAGACT TCCAAATATC CATACCTGCT	120

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GGTTATAATT AGTGGTGTTC TCAGCCTCTG ATTCTGTCAC CAGGGGTTTT AGAATCATAA	180
ATCCAGATTG ATCTTGGGAG TGTA AAAAAC TGAGGCTCTT TAGCTTCTTA GGACAGCACT	240
TCCTGATTTT GTTTTCAACT TCTAATCCTT TGAGTGTTC TCAATCTGCA GATGCTGAGT	300
TTGTGTGTGA ACGGACACTG AAATATTTTC TAGGAATTGC GGGAGGAAAA TGGGTAGTTA	360
GCTATTTCTG TAAGTATAAT ACTATTTCTC CCCTCCTCCC TTAAACACCT CAGAATTGCA	420
TTTTTACACC TAACATTTAA CACCTAAGGT TTTTGCTGAT GCTGAGTCTG AGTTACCAAA	480
AGGTCCTTAA ATTGTAATAC TAAACTACTT TTATCTTTAA TATCACTTTG TTCAAGATAA	540
GCTGGTGATG CTGGGAAAAT GGGTCTCTTT TATAACTAAT AGGACCTAAT CTGCTCCTAG	600
CAATGTTAGC ATATGAGCTA GGGATTTATT TAATAGTCGG CAGGAATCCA TGTGCARCAG	660
NCAAACCTTAT AATGTTTAAA TTAAACATCA ACTCTGTCTC CAGAAGGAAA CTGCTGCTAC	720
AAGCCTTATT AAAGGGCTGT GGCTTTAGAG GGAAGGACCT CTCCTCTGTC ATTCTTCCTG	780
TGCTCTTTTG TGAATCGCTG ACCTCTCTAT CTCCTGAAAA AGAGCACGTT CTTCTGCTGT	840
ATGTAACCTG TCTTTTCTAT GATCTCT	867

(2) INFORMATION FOR SEQ ID NO:29:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 561 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:29:

NAAAAACGGG GNNGGGANTG GGCCTTAAAN CCAAAGGGCN AACTCCCCAA CCATTNAAAA	60
ANTGACNNGG GATTATTAAA ANCGGCGGGA AACATTTTAC NGCCCAACTA ATATTGTTAA	120
ATTAAACCA CCACCNCTGC NCCAAGGAGG GAAACTGCTG CTACAAGCCT TATTAAAGGG	180
CTGTGGCTTT AGAGGGAAGG ACCTCTCCTC TGTCATTCTT CCTGTGCTCT TTTGTGAATC	240

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GCTGACCTCT CTATGTCCGT GAAAAGAGCA CGTTCTTCGT CTGTATGTAA CCTGTCTTTT	300
CTATGATCTC TTTAGGGGTG ACCCAGTCTA TTAAAGAAAG AAAAATGCTG AATGAGGTAA	360
GTA CTTGATG TTACAACTA ACCAGAGATA TTCATTCACT CATATAGTTA AAAATGTATT	420
TGCTTCCTTC CATCAATGCA CCACTTTCCT TAACAATGCA CAAATTTTCC ATGATAATGA	480
GGATCATCAA GAATTATGCA GGCCTGCACT GTGGCTCATA CCTATAATCC CAGCGCTTTG	540
GGAGGCTGAG GCGCTTGGAT C	561

(2) INFORMATION FOR SEQ ID NO:30:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 567 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:30:

AATTTTTTGT ATTTTATAGTA GAGATGAGGT TCACCATGTT GGTCTAGATC TGGTGTGCGAA	60
CGTCCTGACC TCAAGTGATC TGCCAGCCTC AGTCTCCCAA AGTGCTAGGA TTACAGGGGT	120
GAGCCACTGC GCCTGGCCTG AATGCCTAAA ATATGACGTG TCTGCTCCAC TTCCATTGAA	180
GGAAGCTTCT CTTTCTCTTA TCCTGATGGG TTGTGTTTGG TTTCTTTCAG CATGATTTTG	240
AAGTCAGAGG AGATGTGGTC AATGGAAGAA ACCACCAAGG TCCAAAGCGA GCAAGAGAAT	300
CCCAGGACAG AAAGGTAAAG CTCCCTCCCT CAAGTTGACA AAAATCTCAC CCCACCACTC	360
TGTATTCCAC TCCCCTTTGC AGAGATGGGC CGCTTCATTT TGTAAGACTT ATTACATACA	420
TACACAGTGC TAGATACTTT CACACAGGTT CTTTTTTCAC TCTCCATCC CAACCACATA	480
AATAAGTATT GTCTCTACTT TATGAATGAT AAAACTAAGA GATTAGAGA GGCTGTGTAA	540
TTTGGAATCC CGTCTCGGGT TCAGATC	567

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(2) INFORMATION FOR SEQ ID NO:31:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 633 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:31:

TTGGCCTGAT TGGTGACAAA AGTGAGATGC TCAGTCCTTG AATGACAAAG AATGCCTGTA	60
GAGTTGCAGG TCCAAC TACA TATGCACTTC AAGAAGATCT TCTGAAATCT AGTAGTGTTT	120
TGGACATTGG ACTGCTTGTC CCTGGGAAGT AGCAGCAGAA ATGATCGGTG GTGAACAGAA	180
GAAAAAGAAA AGCTCTTCCT TTTTGAAAGT CTGTTTTTTG AATAAAAGCC AATATTCTTT	240
TATAACTAGA TTTTCCTTCT CTCCATTCCC CTGTCCCTCT CTCTTCCTCT CTCCTCCAG	300
ATCTTCAGGG GGCTAGAAAT CTGTTGCTAT GGGCCCTTCA CCAACATGCC CACAGGTAAG	360
AGCCTGGGAG AACCCAGAG TTCCAGCACC AGCCTTTGTC TTACATAGTG GAGTATTATA	420
AGCAAGGTCC CACGATGGGG GTTCCTCAGA TTGCTGAAAT GTTCTAGAGG CTATTCTATT	480
TCTCTACCAC TCTCCAAACA AACAGCACC TAAATGTTAT CCTATGGCAA AAAAAAACTA	540
TACCTTGTC CCCTTCTCAA GAGCATGAAG GTGGTTAATA GTTAGGATTC AGTATGTTAT	600
GTGTTTCAGAT GGCCTTGAGC TGCTGTTAGT GCC	633

(2) INFORMATION FOR SEQ ID NO:32:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 470 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

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(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:32:

TTTGAGAGAC TATCAACCT TATACCAAGT GGCCTTATGG AGACTGATAA CCAGAGTACA	60
TGGCATATCA GTGGCAAATT GACTTAAAT CCATACCCCT ACTATTTTAA GACCATTGTC	120
CTTTGGAGCA GAGAGACAGA CTCTCCATT GAGAGGTCTT GCTATAAGCC TTCATCCGGA	180
GAGTGTAGGG TAGAGGGCCT GGGTTAAGTA TGCAGATTAC TGCAGTGATT TTACATGTAA	240
ATGTCCATTT TAGATCAACT GGAATGGATG GTACAGCTGT GTGGTGCTTC TGTGGTGAAG	300
GAGCTTTCAT CATTACCCT TGGCACAGTA AGTATTGGGT GCCCTGTCAG TGTGGGAGGA	360
CACAATATTC TCTCCTGTGA GCAAGACTGG CACCTGTCAG TCCCTATGGA TGCCCCTACT	420
GTAGCCTCAG AAGTCTTCTC TGCCACATA CCTGTGCCAA AAGACTCCAT	470

(2) INFORMATION FOR SEQ ID NO:33:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 517 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:33:

GGTGGTACGT GTCTGTAGTT CCAGCTACTT GGGAGGCTGA GATGGAAGGA TTGCTTGAGC	60
CCAGGAGGCA GAGGTGGNAN NTTACGCTGA GATCACACCA CTGCACTCCA GCCTGGGTGA	120
CAGAGCAAGA CCCTGTCTCA AAAACAAACA AAAAAATGA TGAAGTGACA GTTCCAGTAG	180
TCCTACTTTG ACACTTTGAA TGCTCTTTCC TTCCTGGGGA TCCAGGGTGT CCACCCAATT	240
GTGGTTGTGC AGCCAGATGC CTGGACAGAG GACAATGGCT TCCATGGTAA GGTGCCTCGC	300

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ATGTACCTGT GCTATTAGTG GGGTCCTTGT GCATGGGTTT GGTTTATCAC TCATTACCTG	360
GTGCTTGAGT AGCACAGTTC TTGGCACATT TTAAATATT TGTGAATGA ATGGCTAAAA	420
TGTCTTTTGT ATGTTTTTAT TGTTATTGT TTTATATTGT AAAAGTAATA CATGAACTGT	480
TTCCATGGGG TGGGAGTAAG ATATGAATGT TCATCAC	517

(2) INFORMATION FOR SEQ ID NO:34:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 434 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iv) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:34:

CAGTAATCCT NAGAACTCAT ACGACCGGGC CCCTGGAGTC GNTGNTTNGA GCCTAGTCCN	60
GGAGAATGAA TTGACACTAA TCTCTGCTTG TGTCTCTGT CTCCAGCAAT TGGGCAGATG	120
TGTGAGGCAC CTGTGGTGAC CCGAGAGTGG GTGTTGGACA GTGTAGCACT CTACCACTGC	180
CAGGAGCTGG ACACCTACCT GATACCCCAG ATCCCCACA GCCACTACTG ACTGCAGCCA	240
GCCACAGGTA CAGAGCCACA GGACCCCAAG AATGAGCTTA CAAAGTGCC TTTCCAGGCC	300
CTGGGAGCTC CTCTCACTCT TCAGTCCTTC TACTGTCCTG GCTACTAAAT ATTTTATGTA	360
CATCAGCCTG AAAAGGACTT CTGGCTATGC AAGGGTCCCT TAAAGATTTT CTGCTTGAAG	420
TCTCCCTTGG AAAT	434

(2) INFORMATION FOR SEQ ID NO:35:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

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(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:35:

GATAAATTAA AACTGCGACT GCGCGGCGTG

30

(2) INFORMATION FOR SEQ ID NO:36:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 30 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:36:

GTAGTAGAGT CCCGGGAAAG GGACAGGGGG

30

(2) INFORMATION FOR SEQ ID NO:37:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 30 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:37:

ATATATATAT GTTTTCTAA TGTGTTAAAG

30

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(2) INFORMATION FOR SEQ ID NO:38:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:38:

GTAAGTCAGC ACAAGAGTGT ATTAATTGG

30

(2) INFORMATION FOR SEQ ID NO:39:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:39:

TTTCTTTTTC TCCCCCCCCT ACCCTGCTAG

30

(2) INFORMATION FOR SEQ ID NO:40:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

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- (vi) ORIGINAL SOURCE:
(A) ORGANISM: *Homo sapiens*

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:40:

GTAAGTTTGA ATGTGTTATG TGGCTCCATT

30

- (2) INFORMATION FOR SEQ ID NO:41:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (iii) HYPOTHETICAL: NO

- (vi) ORIGINAL SOURCE:
(A) ORGANISM: *Homo sapiens*

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:41:

AGCTACTTTT TTTTTTTTTT TTTGAGACAG

30

- (2) INFORMATION FOR SEQ ID NO:42:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (iii) HYPOTHETICAL: NO

- (vi) ORIGINAL SOURCE:
(A) ORGANISM: *Homo sapiens*

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:42:

GTAAGTGCAC ACCACCATAT CCAGCTAAAT

30

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(2) INFORMATION FOR SEQ ID NO:43:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:43:

AATTGTTCTT TCTTTCTTTA TAATTTATAG

30

(2) INFORMATION FOR SEQ ID NO:44:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:44:

GTATATAATT TGGTAATGAT GCTAGGTTGG

30

(2) INFORMATION FOR SEQ ID NO:45:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

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- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:45:

GAGTGTGTTT CTCAAACAAT TTAATTTTCAG

30

- (2) INFORMATION FOR SEQ ID NO:46:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:46:

GTAAGTGTTG AATATCCCAA GAATGACACT

30

- (2) INFORMATION FOR SEQ ID NO:47:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:47:

AAACATAATG TTTTCCCTTG TATTTTACAG

30

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(2) INFORMATION FOR SEQ ID NO:48:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:48:

GTAAAACCAT TTGTTTCTT CTTCTTCTTC

30

(2) INFORMATION FOR SEQ ID NO:49:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:49:

TGCTTGACTG TTCTTTACCA TACTGTTTAG

30

(2) INFORMATION FOR SEQ ID NO:50:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

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- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:50:

GTAAGGGTCT CAGGTTTTTT AAGTATTTAA

30

- (2) INFORMATION FOR SEQ ID NO:51:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (iii) HYPOTHETICAL: NO

- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:51:

TGATTTATTT TTTGGGGGGA AATTTTTTAG

30

- (2) INFORMATION FOR SEQ ID NO:52:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (iii) HYPOTHETICAL: NO

- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:52:

GTGAGTCAAA GAGAACCTTT GTCTATGAAG

30

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(2) INFORMATION FOR SEQ ID NO:53:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:53:

TCTTATTAGG ACTCTGTCTT TTCCCTATAG

30

(2) INFORMATION FOR SEQ ID NO:54:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:54:

GTAATGGCAA AGTTTGCCAA CTTAACAGGC

30

(2) INFORMATION FOR SEQ ID NO:55:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

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(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:55:

GAGTACCTTG TTATTTTGT ATATTTTCAG

30

(2) INFORMATION FOR SEQ ID NO:56:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:56:

GTATTGGAAC CAGGTTTTTG TGTTTGCCCC

30

(2) INFORMATION FOR SEQ ID NO:57:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:57:

ACATCTGAAC CTCTGTTTT GTTATTAAAG

30

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(2) INFORMATION FOR SEQ ID NO:58:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:58:

AGGTAAAAAG CGTGTGTGTG TGTGCACATG

30

(2) INFORMATION FOR SEQ ID NO:59:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:59:

CATTTTCTTG GTACCATTTA TCGTTTTTGA

30

(2) INFORMATION FOR SEQ ID NO:60:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

-174-

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:60:

GTGTGTATTG TTGGCCAAAC ACTGATATCT

30

(2) INFORMATION FOR SEQ ID NO:61:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:61:

AGTAGATTTG TTTTCTCATT CCATTAAAG

30

(2) INFORMATION FOR SEQ ID NO:62:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:62:

GTAAGAAACA TCAATGTAAA GATGCTGTGG

30

-175-

(2) INFORMATION FOR SEQ ID NO:63:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:63:

ATGGTTTTCT CCTTCCATTT ATCTTTCTAG

30

(2) INFORMATION FOR SEQ ID NO:64:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:64:

GTAATATTTTC ATCTGCTGTA TTGGAACAAA

30

(2) INFORMATION FOR SEQ ID NO:65:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

-176-

- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:65:

TGTAAATTAA ACTTCTCCCA TTCCTTTCAG

30

- (2) INFORMATION FOR SEQ ID NO:66:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:66:

GTGAGTGTAT CCATATGTAT CTCCTAATG

30

- (2) INFORMATION FOR SEQ ID NO:67:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
(A) ORGANISM: Homo sapiens

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:67:

ATGATAATGG AATATTGAT TTAATTCAG

30

-177-

(2) INFORMATION FOR SEQ ID NO:68:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:68:

GTATACCAAG AACCTTTACA GAATACCTTG

30

(2) INFORMATION FOR SEQ ID NO:69:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:69:

CTAATCCTTT GAGTGTTTTT CATTCTGCAG

30

(2) INFORMATION FOR SEQ ID NO:70:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

-178-

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:70:

GTAAGTATAA TACTATTTCT CCCCTCCTCC

30

(2) INFORMATION FOR SEQ ID NO:71:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:71:

TGTAACCTGT CTTTTCTATG ATCTCTTTAG

30

(2) INFORMATION FOR SEQ ID NO:72:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: *Homo sapiens*

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:72:

GTAAGTACTT GATGTTACAA ACTAACCAGA

30

-179-

(2) INFORMATION FOR SEQ ID NO:73:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:73:

TCCTGATGGG TTGTGTTTGG TTTCTTTCAG

30

(2) INFORMATION FOR SEQ ID NO:74:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:74:

GTAAAGCTCC CTCCCTCAAG TTGACAAAAA

30

(2) INFORMATION FOR SEQ ID NO:75:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

-180-

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:75:

CTGTCCCTCT CTCTTCCTCT CTTCTTCCAG

30

(2) INFORMATION FOR SEQ ID NO:76:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:76:

GTAAGAGCCT GGGAGAACCC CAGAGTTCCA

30

(2) INFORMATION FOR SEQ ID NO:77:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:77:

AGTGATTTA CATGTAAATG TCCATTTAG

30

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(2) INFORMATION FOR SEQ ID NO:78:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:78:

GTAAGTATTG GGTGCCCTGT CAGTGTGGGA

30

(2) INFORMATION FOR SEQ ID NO:79:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (vi) ORIGINAL SOURCE:
 - (A) ORGANISM: Homo sapiens
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:79:

TTGAATGCTC TTTCCTTCCT GGGGATCCAG

30

(2) INFORMATION FOR SEQ ID NO:80:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO

-182-

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:80:

GTAAGGTGCC TCGCATGTAC CTGTGCTATT

30

(2) INFORMATION FOR SEQ ID NO:81:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:81:

CTAATCTCTG CTTGTGTTCT CTGTCTCCAG

30

(2) INFORMATION FOR SEQ ID NO:82:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 42 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(iii) HYPOTHETICAL: NO

(vi) ORIGINAL SOURCE:

(A) ORGANISM: Homo sapiens

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:82:

Cys Pro Ile Cys Leu Glu Leu Ile Lys Glu Pro Val Ser Thr Lys Cys
 1 5 10 15

Asp His Ile Phe Cys Lys Phe Cys Met Leu Lys Leu Leu Asn Gln Lys
 20 25 30

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Lys Gly Pro Ser Gln Cys Pro Leu Cys Lys
 35 40

(2) INFORMATION FOR SEQ ID NO:83:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 45 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(iii) HYPOTHETICAL: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:83:

Cys Pro Ile Cys Leu Glu Leu Lys Glu Pro Val Ser Ala Asp Cys
 1 5 10 15
 Asn His Ser Phe Cys Arg Ala Cys Ile Thr Leu Asn Tyr Glu Ser Asn
 20 25 30
 Arg Asn Thr Asp Gly Lys Gly Asn Cys Pro Val Cys Arg
 35 40 45

(2) INFORMATION FOR SEQ ID NO:84:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 41 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(iii) HYPOTHETICAL: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:84:

Cys Pro Ile Cys Leu Asp Met Leu Lys Asn Thr Met Thr Thr Lys Glu
 1 5 10 15
 Cys Leu His Arg Phe Cys Ser Asp Cys Ile Val Thr Ala Leu Arg Ser
 20 25 30
 Gly Asn Lys Glu Cys Pro Thr Cys Arg
 35 40

-184-

(2) INFORMATION FOR SEQ ID NO:85:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 42 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(iii) HYPOTHETICAL: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:85:

Cys Pro Val Cys Leu Gln Tyr Phe Ala Glu Pro Met Met Leu Asp Cys
1 5 10 15

Gly His Asn Ile Cys Cys Ala Cys Leu Ala Arg Cys Trp Gly Thr Ala
20 25 30

Cys Thr Asn Val Ser Cys Pro Gln Cys Arg
35 40

Claims:

1. An isolated nucleic acid coding for a mutant or polymorphic BRCA1 polypeptide, said nucleic acid containing in comparison to the BRCA1 polypeptide encoding sequence set forth in
5 SEQ.ID No:1 one or more mutations or polymorphisms selected from the mutations set forth in Tables 12, 12A and 14 and the polymorphisms set forth in Tables 18 and 19.

2. An isolated nucleic acid as claimed in claim 1 which is a DNA coding for a mutant BRCA1 polypeptide, said DNA containing in comparison to the BRCA1 polypeptide encoding sequence
10 set forth in SEQ.ID No: 1 one or more mutations set forth in Tables 12, 12A and 14.

3. An isolated nucleic acid as claimed in claim 1 which is a DNA coding for a polymorphic BRCA1 polypeptide, said DNA containing in comparison to the BRCA1 polypeptide encoding sequence set forth in SEQ.ID No:1 one or more polymorphisms set forth in Tables 18 and 19.
15

4. A nucleic acid probe wherein the nucleotide sequence is a portion of a nucleic acid as claimed in any one of claims 1 to 3 including a mutation or polymorphism compared to the nucleotide sequence set forth in SEQ.ID No: 1 selected from the mutations set forth in Tables 12, 12A and 14 and the polymorphisms set forth in Tables 18 and 19.
20

5. A replicative cloning vector which comprises an isolated DNA according to any one of claims 1 to 4 and a replicon operative in a host cell for said vector.

6. An expression vector which comprises an isolated DNA according to any one of claims 1 to 4 wherein the coding sequence for said mutant or polymorphic BRCA1 polypeptide is operably-linked to a promoter sequence capable of directing expression of said coding sequence in host cells for said vector.
25

7. Host cells transformed with a vector as claimed in claim 5 or claim 6.
30

8. A method of producing a mutant or polymorphic BRCA1 polypeptide compared to the BRCA1 polypeptide having the amino acid sequence set forth in SEQ.ID No:2 which comprises (i) culturing host cells as claimed in claim 7 containing an expression vector encoding said polypeptide under conditions suitable for production of said polypeptide and (ii) recovering said polypeptide.
9. A method as claimed in claim 8 which further comprises labelling the recovered polypeptide.
10. A preparation of a polypeptide substantially free of other proteins, said polypeptide being a mutant or polymorphic BRCA1 polypeptide compared to the BRCA1 polypeptide having the amino acid sequence set forth in SEQ.ID No:2 which is obtainable by expression of a nucleotide coding sequence derived from the nucleotide sequence set forth in SEQ.ID No:1 by incorporation of one or more mutations or polymorphisms selected from the mutations set forth in Tables 12, 12A and 14 and the polymorphisms set forth in Tables 18 and 19.
11. A preparation of a polypeptide as claimed in claim 10 which is a mutant BRCA1 polypeptide obtainable by expression of a nucleotide coding sequence derived from the nucleotide sequence set forth in SEQ.ID No:1 by incorporation of a mutation set forth in Tables 12, 12A and 14.
12. A preparation of a polypeptide substantially free of other proteins, said polypeptide being an antigenic fragment of a polypeptide as defined in claim 10 or claim 11 having a mutation or polymorphism compared to the BRCA1 polypeptide having the amino acid sequence set forth in SEQ.ID No:2.
13. A preparation as claimed in any one of claims 10 to 12 wherein said polypeptide is labelled.
14. A polypeptide as defined in any one of claims 10 to 12 which is in the form of a fusion protein.

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15. Use of a polypeptide as defined in any one of claims 10 to 12 and 14 as an immunogen for antibody production.

5 16. A use as claimed in claim 15 wherein one or more antibodies produced are subsequently labelled or bound to a solid support.

17. A method for diagnosing a predisposition for breast and ovarian cancer in a human subject which comprises determining whether there is a germline alteration in the sequence of the
10 BRCA 1 gene in a tissue sample of said subject compared to the nucleotide sequence set forth in SEQ.ID No:1 or a wild-type allelic variant thereof, said alteration indicating a predisposition to said cancer being selected from the mutations as set forth in Tables 12, 12A and 14.

18. A method for diagnosing a breast or ovarian lesion of a human subject for neoplasia
15 associated with the BRCA1 gene locus, which comprises determining whether there is a mutation in the sequence of the BRCA1 gene in a sample from said lesion compared to the nucleotide sequence set forth in SEQ.ID No.1 or a wild-type allelic variant thereof, said mutation being selected from the mutations as set forth in Tables 12, 12A and 14.

20 19. A method as claimed in claim 17 or claim 18 which comprises analyzing mRNA or protein of said sample to determine whether an expression product is present indicative of expression of a mutant BRCA1 allele as defined in claim 1.

25 20. A method as claimed in claim 19 wherein the mRNA encoded by the BRCA1 gene in said sample is investigated.

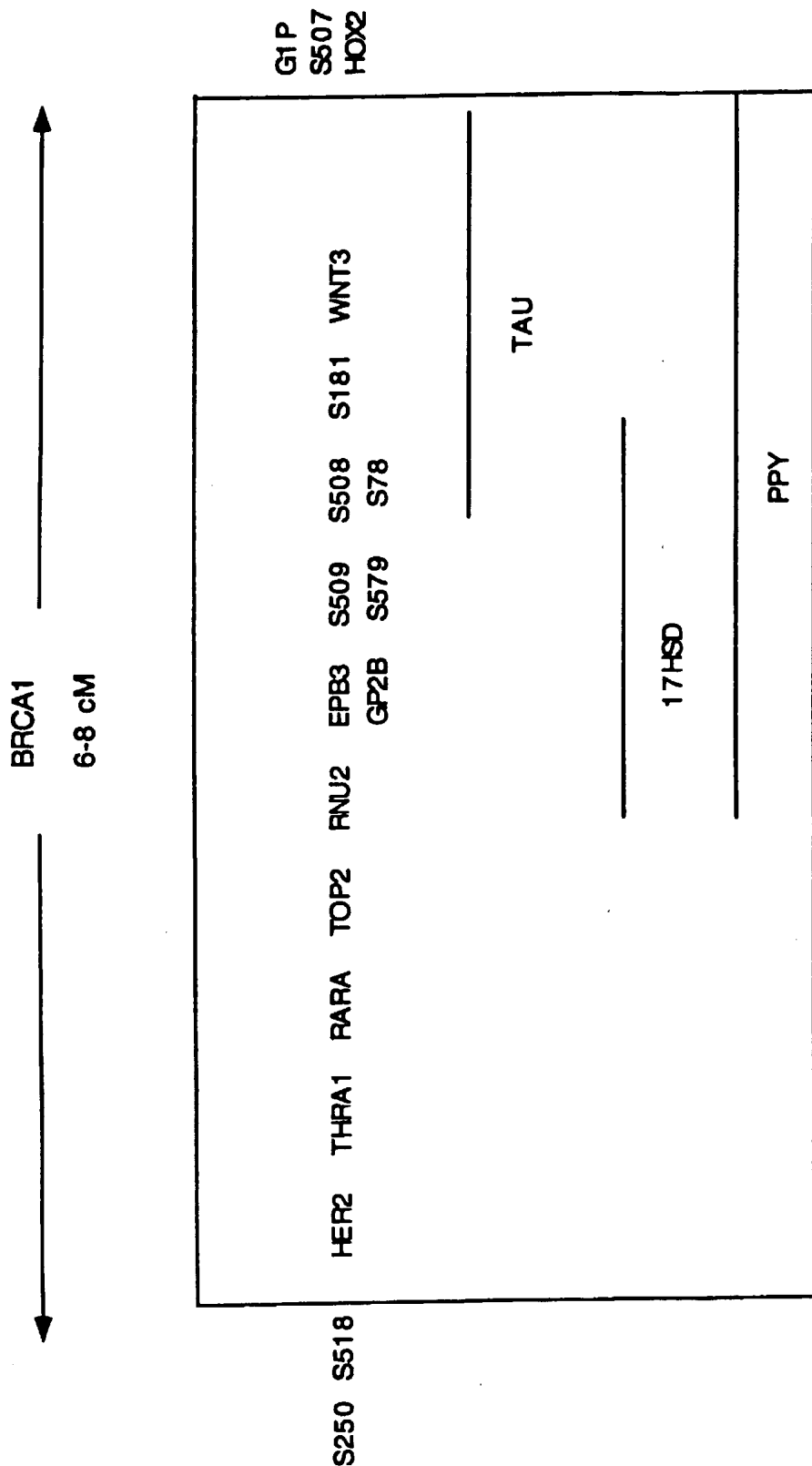
21. A method as claimed in claim 20 wherein mRNA from said sample is contacted with a BRCA1 gene probe under conditions suitable for hybridization of said probe to an RNA corresponding to said BRCA1 gene and hybridization of said probe is determined.

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22. A method as claimed in claim 17 or claim 18 wherein a BRCA1 gene probe is contacted with genomic DNA isolated from said sample under conditions suitable for hybridization of said probe to said gene and hybridization of said probe is determined.
- 5 23. A method as claimed in claim 21 or claim 22 wherein said probe is an allele-specific probe for a mutant BRCA1 allele as defined in claim 1.
24. A method as claimed in claim 17 or claim 18 which comprises determining whether there is a mutation in the BRCA1 gene in said sample by observing shifts in electrophoretic mobility
10 of single-stranded DNA from said sample on non-denaturing polyacrylamide gels.
25. A method as claimed in claim 17 or claim 18 wherein all or part of the BRCA1 gene in said sample is amplified and the sequence of said amplified sequence is determined.
- 15 26. A method as claimed in claim 17 or claim 18 wherein oligonucleotide primers are employed which are specific for a mutant BRCA1 allele as defined in claim 1 to determine whether said allele is present in said sample by nucleic acid amplification.
27. A method as claimed in claim 17 or claim 18 wherein all or part of the BRCA1 gene in said
20 sample is cloned to produce a cloned sequence and the sequence of said cloned sequence is determined.
28. A method as claimed in any one of claims 17 to 20 which comprises determining whether there is a mismatch between molecules (1) BRCA1 gene genomic DNA or BRCA1 mRNA
25 isolated from said sample, and (2) a nucleic acid probe complementary to human wild-type BRCA1 gene DNA, when molecules (1) and (2) are hybridized to each other to form a duplex.
29. A method as claimed in any one of claims 17 to 20 wherein amplification of BRCA1 gene sequences in said sample is carried out and hybridization of the amplified sequences to one or
30 more nucleic acid probes which comprise a wild-type BRCA1 gene sequence or a mutant BRCA1 gene sequence as defined in claim 1 is determined.

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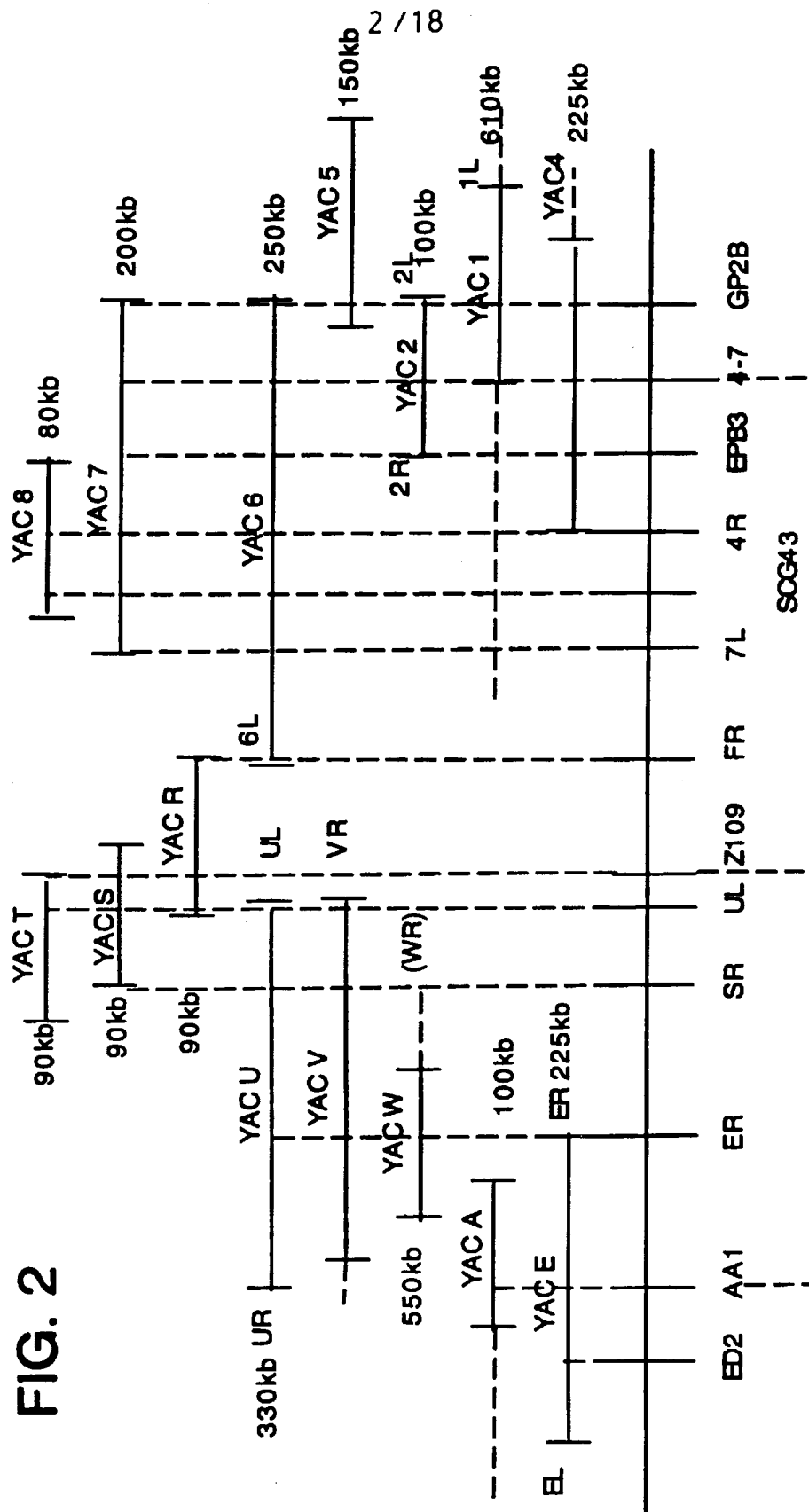
30. A method as claimed in claim 17 or claim 18 which comprises determining *in situ* hybridization of the BRCA1 gene in said sample with one or more nucleic acid probes which comprise a wild-type BRCA1 gene sequence or a mutant BRCA1 gene sequence as defined in
5 claim 1.



Map of the early onset breast and ovarian cancer region (BRCA1)

FIG. 1

FIG. 2



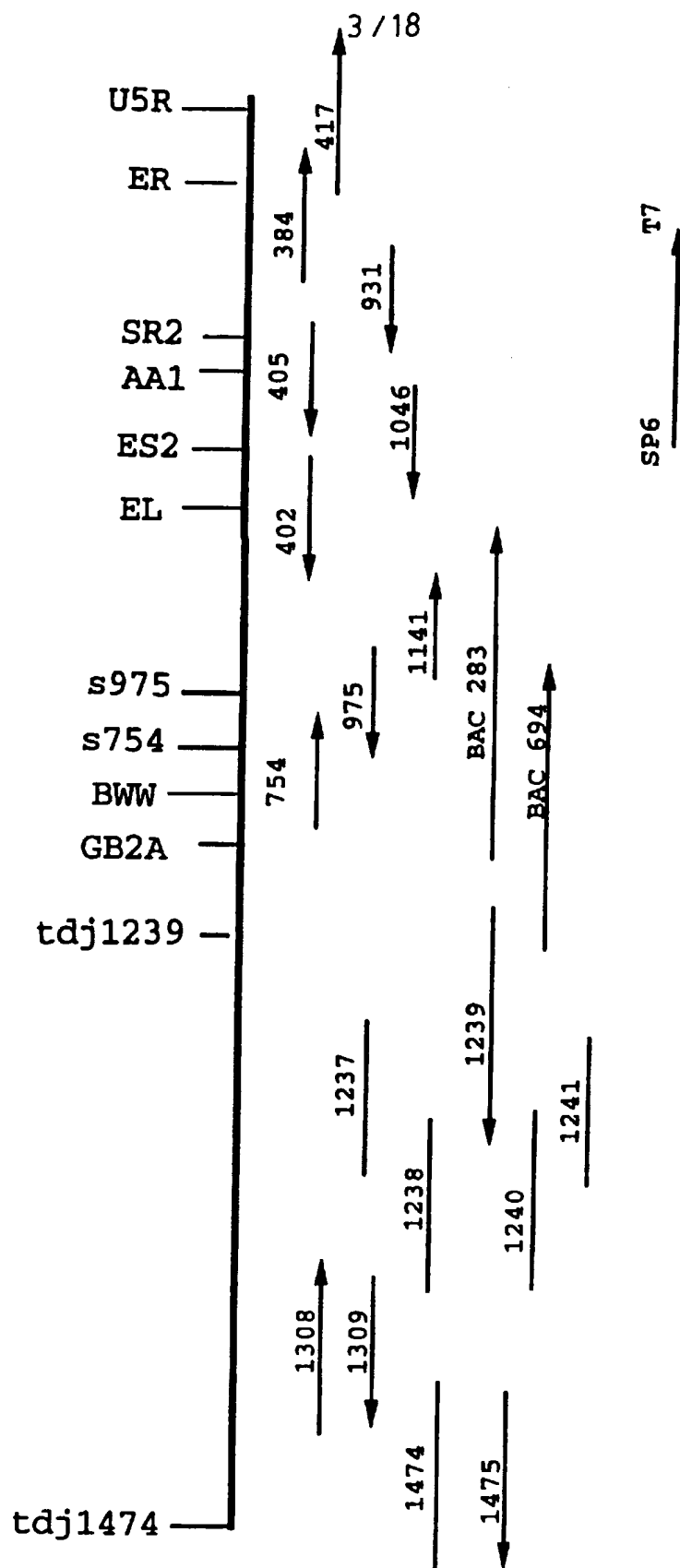
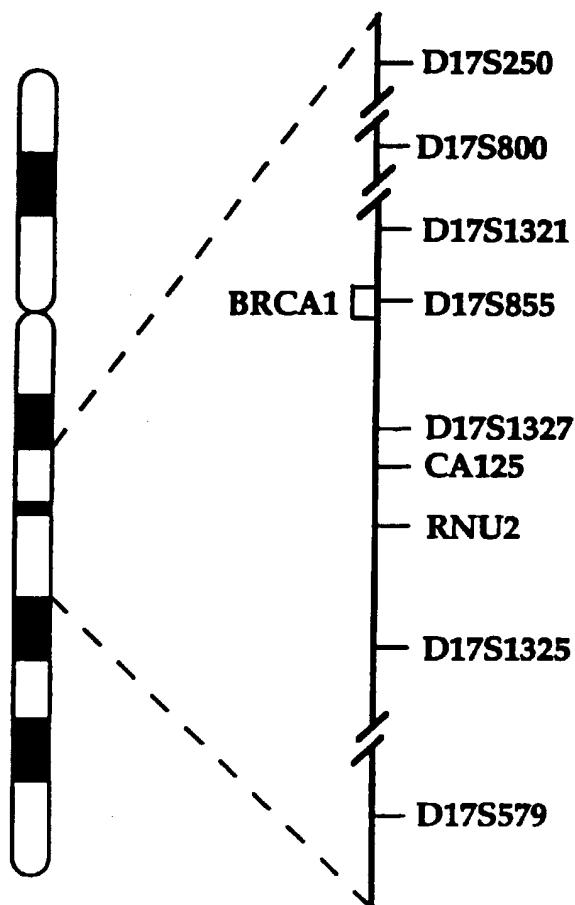


FIG. 3

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FIG. 4



SEQ. ID
NO:

82 BRCA1
83 RPT1
84 RIN1
85 RFP1
C3HC4 motif

CPICLELIKEPVSTK-CDHIFCKFCMLKLLNQKK---GPSQCPLCK
CPICLELLKEPVSAD-CNHSFCRACITLNYESNRNTDGKGNCPVCR
CPICLDMLKNTMTTKECLHRFCSDCIVTALRS-----GNKECPTCR
CPVCLQYFAEPMMLD-CGHNICCACLARCWGTAC---TNVSCPQCR
C--C-----C-H--C--C-----C--C

FIG. 5

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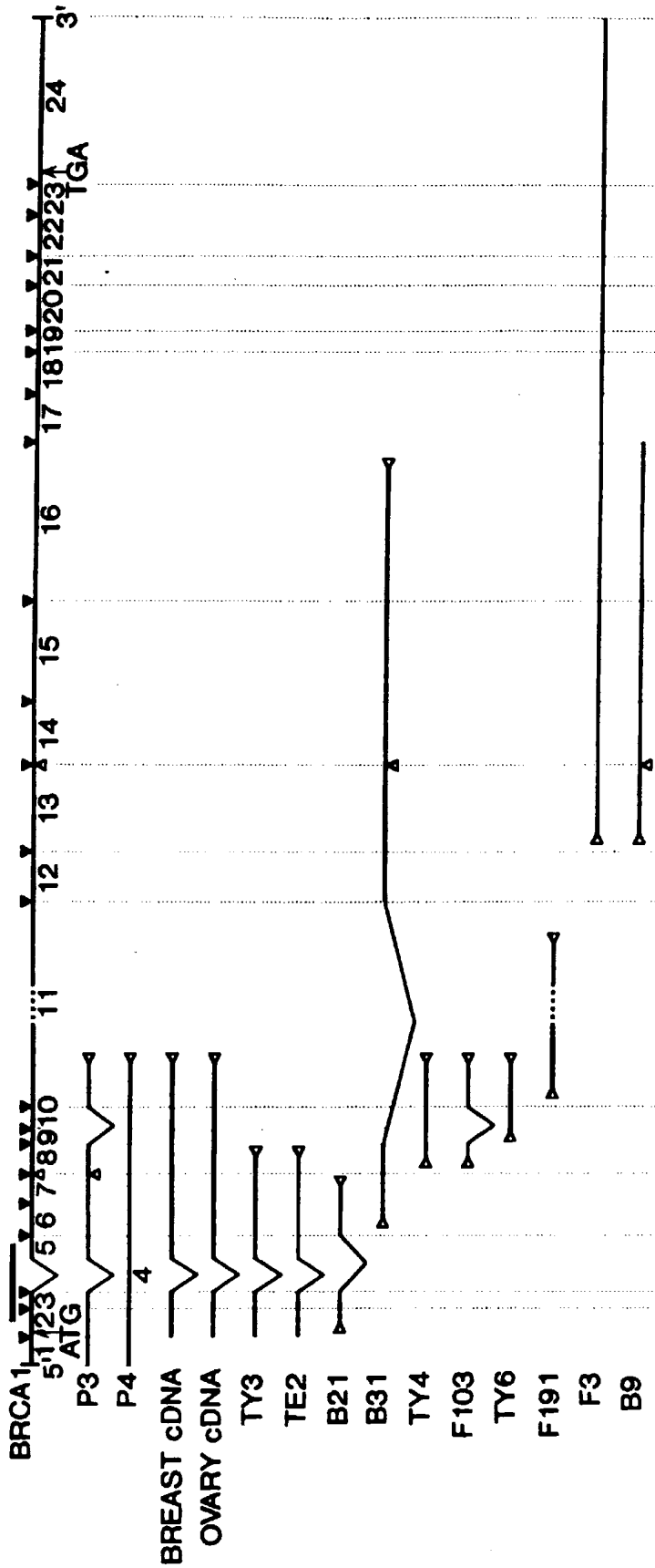


FIG. 6

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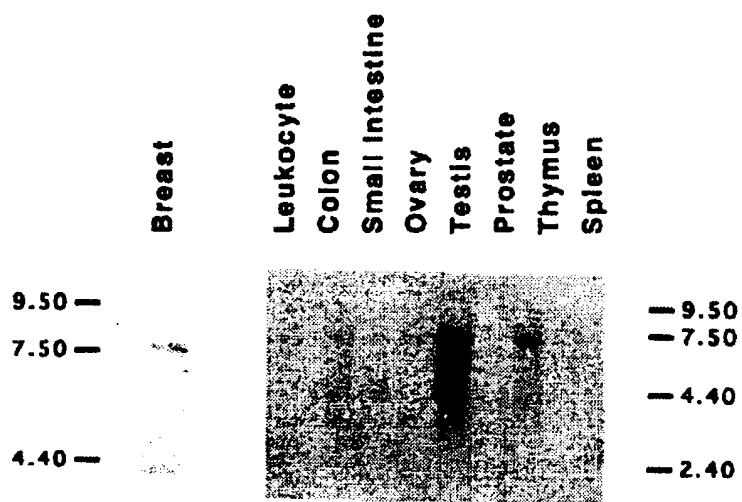


FIG. 7

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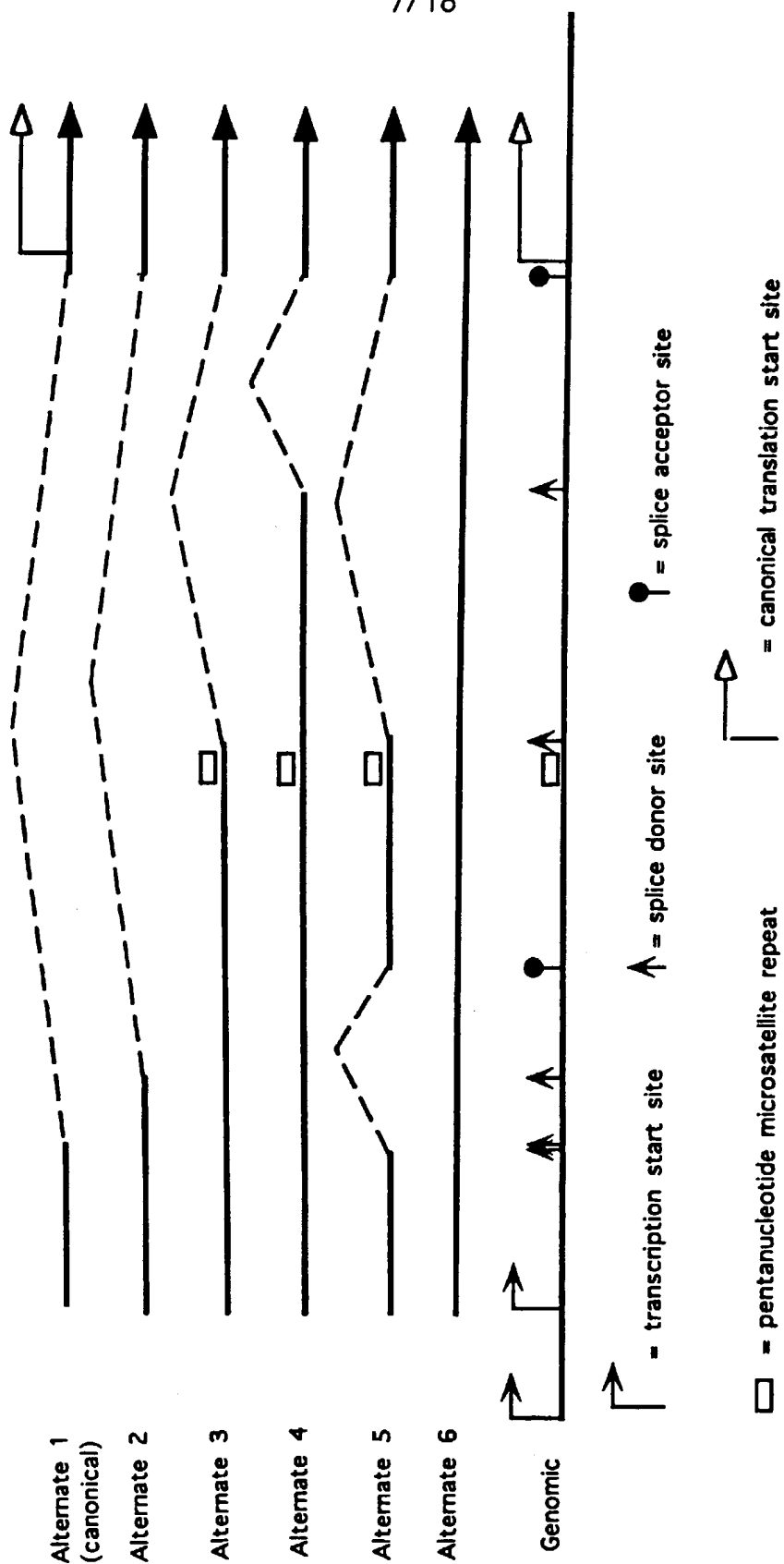


FIG. 8

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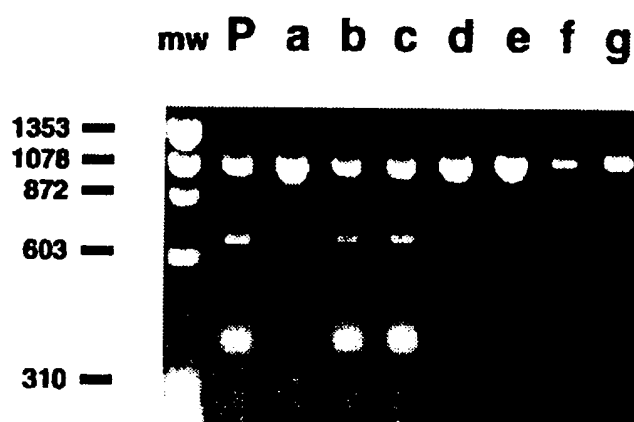


FIG. 9A

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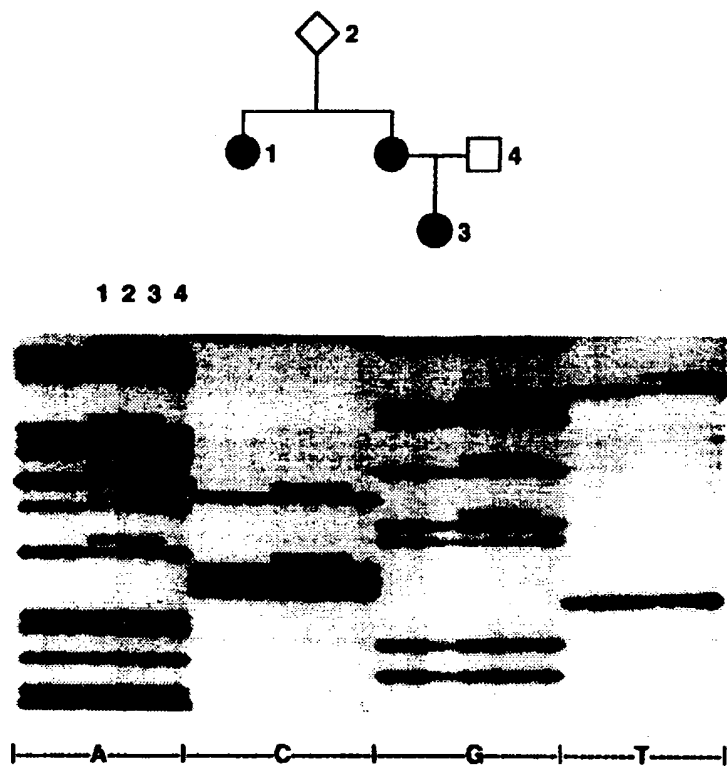
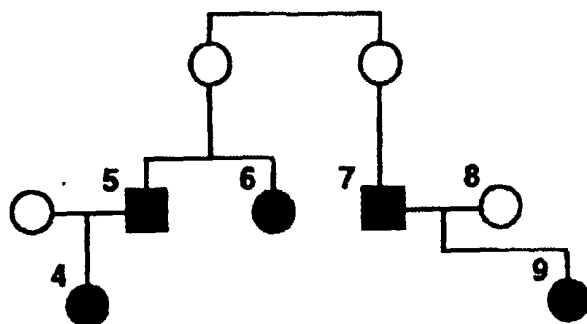


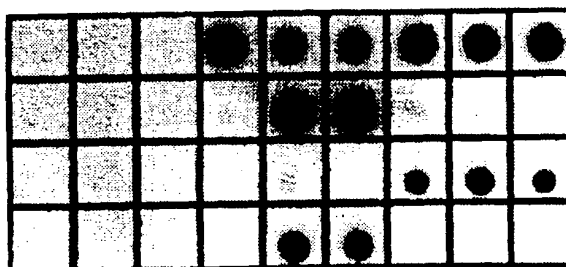
FIG. 9B

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PM1

4 5 6 7 8 9

A
G
A
G

PM7

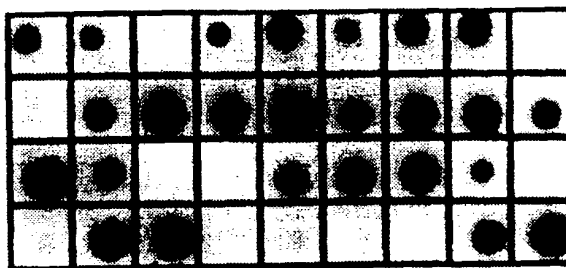
A
G
A
G

FIG. 9C

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1 gaggctagagggcaggcactttatggcaaaactcaggtagaattcttctcttccgtctct
61 ttccttttacgtcatcgaggagactgggtggcaatcgagcccgagagacgcatggctct
121 ttctgccctccatcctctgatgtaccttgatttcgtattctgagaggctgctgcttagcg
181 gtagcccttgggtttccgtggcaacggaaaagcgcggaattacagataaattaaaactg
241 cgactgcgcggcgtgAGCTCGCTGAGACTTCCTGGACCCCGCACCAGGCTGTGGGGTTTC
301 TCAGATAACTGGGCCCTGCGCTCAGGAGGCCTTCACCTCTGCTCTGGGTAAAGgtagt
361 agagtccccgggaaagggacagggggcccaagtgatgctctggggtaactggcgtaggagag
421 tggatttccgaagctgacagatgggtattctttgacgggggtagggcggaacctgaga
481 ggcgtaaggcgttgtaaccctggggaggggggaggtttgtaggctcgcgagggaagcgct
541 gaggatcaggaagggggcactgagtgctcggtgggggaatcctcgtagaggaactggaat
601 atgccttgagggggacactatgtcttataaaacgtcggtggtcatgaggtcaggagttc
661 cagaccagcctgaccaacgtggtgaaactcgtctctactaaaaatacnaaaattagccg
721 ggcgtggtgccgtccagctactcaggaggctgaggcaggagaatcgctagaaccggga
781 ggcggaggttgagtgagccgagatcgcgccattgcactccagcctggcgacagagcga
841 gactgtctcaaaacaaaaacaaaaacaaaaacaaaaacaccggctggtatgtatgag
901 aggatgggaccttggtggaagaagagggtgccaggaatatgtctgggaagggaggagacag
961 gattttgtgggaggggagaacttaagaactggatccatttgcgccattgagaaagcgcaag
1021 agggaagttagaggagcgtcagtagtaacagatgctgccggcagggaatgtgcttgaggagg
1081 atccagagatgagagcaggtcactgggaaaggttagggcggggaggccttgattgggtgt
1141 tggtttggctcgttggtgattttggttttatgcaaaaaagaaaaacaaccagaaacattg
1201 gagaaagctaaggctaccaccacctaccgggtcagtcactcctctgtagctttctcttct
1261 ttggagaaaggaaaagacccaaggggttggcagcgatatgtgaaaaaattcagaatttat
1321 gttgtctaattacaaaaagcaacttctagaatcttataaaataaaggacgttgctcattag
1381 ttcttctggtttgtattatttctaaaaccttccaaatcttcaaatttactttattttaaaa
1441 tgataaaatgaagttgtcattttataaaaccttttaaaaagatatatatatgttttct
1501 aatgtgttaaagTTCATTGGAACAGAAAGAAATGGATTATCTGCTCTTCGCGTTGAAGA
1561 AGTACAAAATGTCATTAAATGCTATGCAGAAAATCTTAGAGTGTCCCATCTGgtaagttag
1621 cacaagagtgatttaatttgggattcctatgattatctcctatgcaaatgaacagaattg
1681 accttacatactaggggaagaaaagacatgtctagtaagattaggctatttgaattgctga
1741 ttttcttaactgaagaactttaaaaatatagaaaatgattccttggttctccatccactct
1801 gccctctccactcctctccttttcaacacaatcctgtggtccgggaaagacagggctctg
1861 tcttgattgggtctgcactgggcaggatctggttagatactgcatttgctttctccagctc
1921 taaavvvvvvvvvvvvvaatgctgatgatagtagtattgaagggatcaatataat
1981 tctgttttagatatctgaaagctcactgaaggtaaggatcgatttctctgctgtatttca
2041 gttcctgacacagcagacatttaataaatattgaacgaacttgaggccttatgttgactc
2101 agtcataacagctcaaagttgaacttattcactaagaatagctttatttttaataaatt
2161 attgagcctcattttattttcttttctccccccctaccctgctagTCTGGAGTTGATCA
2221 AGGAACCTGTCTCCACAAAGTGTGACCACATATTTTGCAAgttaagttgaaatgtgttatg
2281 tggctccattattagcttttgttttcttctcctaaccaggaaacacctaactttata
2341 gaagctttactttcttcaattaaagtgagaacgaaaatccaactccatttcttctctc
2401 agagagtatatagttatcaaaagttggttgtaatcatagttcctggtaaagtttgacat
2461 atattatcttttttttttttgagacaagctctcgctctgctcgccaggctggagtgacgt
2521 ggcagtagggttgctcactgcacctccgccccgagttcagcgactctvvvvvvvvvvv
2581 vtgagatctagaccacatggtcaaaagagatagaatgtgagcaataaatgaaccttaaat
2641 tttcaacagctacttttttttttttttttgagacagGGKCTTACTCTGTTGTCCACGCT
2701 GGAGTACAGWGTGCGATCATGAGGCTTACTGTTGCTTGACTCCTAGGCTCAAGCGATCCT
2761 ATCACCTCAGTCTCCAAGTAGCTGGACTgtaagtgcacaccaccatatccagctaaattt
2821 tgtgttttctgtagagacggggttccgcatgtttcccaggctggtccttgaactttgggc
2881 ttaaccgctctgccacctaggcatcccaaagtgctaggattacaggtgtgagtcacat
2941 gcctggccagtttttaggttagctctgtcttttcaagtcataatacaagttcattttcttt
3001 taagtttagttaacaaccttatatcatgtattcttttctagcataaagaaagattcgagg

FIG. 10A

SUBSTITUTE SHEET (RULE 26)

[illegible]

FIG. 10B

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6121 gtgattggaatgtatatcaagtatcagcttcaaaatatgctatattaataacttcaaaaat
6181 tacacaaataatacataatcaggtttgaaaaatttaagacaacmsaaraaaaaawycmaa
6241 tcacamatatcccacacattttattatmtctmctmcwattattttgwagagmctgggtct
6300 cacycykttgctwatgctgggtctttgaacyccykgccycaarcartcctscctccabcctc
6361 ccaargtgctggggatwataggcatgarctaaccgcacccagccccagacatttttagtgt
6421 gtaaattcctgggcattttttcaaggcatcatacatgttagctgactgatgatgggtcaat
6481 ttattttgtccatgggtgtcaagtttctcttcaggaggaaaagcacagaactggccaagaa
6541 ttgcttgactgttctttaccatactgttttagCAGGAAACAGTCTCAGTGTCCAACCTCTC
6601 TAACCTTGGAACTGTGAGAACTCTGAGGACAAAGCAGCGGATACAACCTCAAAAGACGTC
6661 TGCTTACATTGAATTGGgttaaggggtctcaggttttttaagtatttaataataattgctgg
6721 attccttatcttatagttttgccccaaatcttggtcataatttgattttggttaggcag
6781 ctttggggaagtgaattttatgagccctatggtgagttataaaagttaaaagacgcagt
6841 tcccaccttgaagaatcttactttaaaaagggagcaaaagaggccaggtggtggctca
6901 cacctgtaatcccagcactttgggaggccaaagtgggtggatcacctgaggtcgggagtt
6961 cgagaccagcctagccaacatggagaaactctgtctgtacaaaaaaataaaaaattagcc
7021 aggtgtgggtggcacataactgtaatcccagctactcgggagggtgaggcaggagaatcac
7081 ttgaacccgggaggtggaggttgcggtgaaccgagatcgaccattgcactccagcctgg
7141 gcaaaaaatagcgaactccatctaaaaaagagagcaaaagaaagamtmtctggt
7201 ttttaamtmtgtgtaaatatgtttttggaagatggagagtagcaataagaaaaaacatga
7261 tggattgtacagtattttagttccaagataaattgtactagatgaggaagccttttaaga
7321 agagctgaattgccaggcgcagtggtcacgcctgtaatcccagcactttgggaggccga
7381 ggtgggaggatcacctgaggtcgggagttcaagaccagcctgaccaacatggagaaaccc
7441 catctctactaaaaaaaaaaaaaaaaaattagccgggtgggtggcttatgcctgtaatc
7501 ccagctactcaggaggctgaggcaggagaatcgcttgaaccagggaagcagaggttgag
7561 tgagccaagatcgaccattgcactccagcctaggcaacaagagtgaactccatctcaa
7621 aaaaaaaaaaaaaagagctgaatcttggtgggcaggatgggtcgtgcctgtaatcctaac
7681 gctttggaagaccgaggcagaaggattggttgagtcacagagtttaagaccagcctggcc
7741 aacataggggaaccctgtctctatttttaaaataataatacatttttgccgggtgcggtg
7801 gctcatgcctgtaatcccaatactttgggaggctgaggcaggtagatcacctgaggtcag
7861 agttcgagaccagcctggataacctggtgaaacccctcttactaaaaatacaaaaaaaa
7921 aaaaaaattagctgggtgtggttagcacatgcttgtaatcccagctacttgggaggctgag
7981 gcaggagaatcgcttgaaccaggaggcggagggttacaatgagccaacactacaccactg
8041 cactccagcctgggcaatagagttagactgcatctcaaaaaataataatttttaaaaat
8101 aataaatttttttaagcttataaaaaagaaaagttagggccagcatagtagctcacatctg
8161 taatctcagcagtggcagaggattgcttgaagccaggagtttgagaccagcctgggcaac
8221 atagcaagacctcatctctacaaaaaatttcttttttaaattagctgggtgtggtggtg
8281 tgcactgttagtcccagctactcaggaggcagaggtgagtggtatcattgaaccaggag
8341 tttgaggctgtagttagctatgatcatgccactgcactccaacctgggtgacagagcaag
8401 acctcaaaaaaaaaaaaaaagagctgctgagctcagaattcaaaactgggtctctcaaat
8461 tggattttcttttagaatatatttataattaaaaaggatagccatcttttgagctcccag
8521 gcaccaccatctatttatcataacacttactgtttcccccccttatgatcataaattcct
8581 agacaacaggcattgtaaaaatagttatagtagttgatatttaggagcacttaactatat
8641 tccaggcactattgtgcttttctgtataactcatttagatgcttgtcagacctctgagat
8701 tgttctattatacttattttacagatgagaaaattaaggcacagagaagttatgaaatt
8761 tttccaaggatttaaacctagtaagtggctgagccatgattcaaacctaggaagtttagat
8821 gtcagagcctgtgcttttttttggtttttggttttcagtagaaacgggggtctca
8881 ctttgggtggccaggctgggtcttgaactcctaacctcaataatccaccatctcggcctc
8941 ctcaagtgtggtgattacaggtgagagccactgtgcctggcgaagcccatgcctttaacc
9001 acttctctgtattacatactagcttaactagcattgtacctgccacagtagatgctcagt
9061 aaatatttctagttgaatatctgtttttcaacaagtacatttttttaacccttttaatta
9121 agaaaacttttattgatttttttttgggggggaaatttttttagGATCTGATTCTTCTGAA

FIG. 10C

SUBSTITUTE SHEET (RULE 26)

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9181 GATACCGTTAATAAGGCAACTTATTGCAGgtgagtcaaagagaacctttgtctatgaagc
9241 tgggtatttttctatttagttaatattaaggattgatgtttctctcttttaaaaaatattt
9301 taactttttatttttaggttcagggatgtatgtgcagtttgttatataggtaaacacacgac
9361 ttgggattttgggtgtagatattttttcatcatccgggtactaagcataccccacagtttt
9421 ttgtttgtctttctttctgaattttctccctcttcccaccttctccctcaagtaggctgggt
9481 gtttctccagactagaatcatgggtattggaagaaaccttagagatcatctagtttagttc
9541 tctcattttatagtgaggaaataccctttttgtttgttggatttagttattagcactgt
9601 ccaaaggaatttaggataacagtagaactctgcacatgcttgcttctagcagattgttct
9661 ctaagtctctcatatacagtaatttgacacagcagtaattgtgactgatgaaaatgttc
9721 aaggacttcattttcaactctttcttctctgttcttatttccacatatctctcaagc
9781 tttgtctgtatgttatataataaactacaagcaacccaactatgttacctaccttctt
9841 aggaattattgtctgacccaggttttttttttttttttttttggagacggggctctgccc
9901 gttgccaggatggagtgtagtgccgcatctcggctcactgcaatctccaactccctgggt
9961 tcaagcgattctcctgtctcaatctcagcagtagctgggactacaggtatacaccaccac
10021 gccccgttaattgaccattccatttctttcttctctcttttttttttttttttttttggaga
10081 cagagtcttgctctgttggccaggctggagtacagaggtgtgatctcacctctccgcaac
10141 gtctgcctcccaggttgaagccatactcctgcctcagcctctctagtagctgggactaca
10201 ggcgcgcgccaccacacccggctaattttttgtatttttagtagagatggggtttcccat
10261 gttggccaggctgggtcttgaactcatgacctcaagtgggtccaccgcctcagcctcccaa
10321 agtgetggaattacaggcttgagccaccgtgccagcaaccatttcatctcaactagaag
10381 tttctaaaggagagagcagctttcactaactaaataagattgggtcagctttctgtaatcg
10441 aaagagctaaaatgtttgatcttgggtcatttgacagttctgcatacatgtaactagtgtt
10501 tcttatttaggactctgtcttttccctatagTGTGGGAGATCAAGAATTGTTACAAATCAC
10561 CCTCAAGGAACAGGGATGAAATCAGTTTGGATTCTGCAAAAAAGGgtaatggcaaagt
10621 ttgccaacttaacaggcactgaaaagagagtgggtagatacagtagtgaattagattat
10681 tctgaagaccatttgggacctttacaacccacaaaatctcttggcagagtttagagtatca
10741 ttctctgtcaaatgtcgtgggtatgggtctgatagattaaatgggtactagactaatgtacc
10801 tataataagaccttcttgaactgattgttgccttttcgctttttttttttttgtttgtttgt
10861 ttgttttttttgagatggggtctcactctgttggccaggctggagtgcagtgatgcaat
10921 cttggctcactgcaacctccacctccaaaggctcaagctatcctcccacttcagcctcct
10981 gagtagctgggactacaggcgcagtgcaccacacccggtaattttttgtgggttttatag
11041 agatgggggtttcaccatgttaccgaggctgggtctcaaaactcctggactcaagcagctctgc
11101 ccacttcagcctcccaaagtgtcagttacaggcttgagccactgtgcctggcctgccc
11161 tttacttttaattgggtgattttgtgtttcatctttacctaactgggttttaaatataggg
11221 agtggtaagtctgtagatagaacagagttaagtagacttaatggccagtaatcttttag
11281 agtacatcagaaccagttttctgatggccaatctgcttttaattcactcttagacgttag
11341 agaaatagggtgtggtttctgcatagggaaaattctgaaattaavvvvvvvvvvvvgatc
11401 ctaagtggaaataatctagggtaaataggaattaaatgaaagagtatgagctacatcttca
11461 gtatacttggtagtttatgaggttagtttctcctaataatagccagttgggtgatttccacc
11521 tccaagggtgatgaagtatgtatttttttaatgacaattcagtttttgagtacctgttta
11581 tttttgtatatatttctagCTGCTTGTGAATTTTCTGAGACGGATGTAACAAATACTGAACA
11641 TCATCAACCCAGTAATAATGATTTGAACACCACTGAGAAGCGTGCAGCTGAGAGGCATCC
11701 AGAAAAGTATCAGGGTAGTTCTGTTTCAAACCTTGCATGTGGAGCCATGTGGCACAAATAC
11761 TCATGCCAGCTCATTACAGCATGAGAACAGCAGTTTATTACTCACTAAAGACAGAATGAA
11821 TGTAGAAAAGGCTGAATTCTGTAATAAAAGCAAACAGCCTGGCTTAGCAAGGAGCCAACA
11881 TAACAGATGGGCTGGAAGTAAGGAAACATGTAATGATAGGCGGACTCCCAGCACAGAAAA
11941 AAAGGTAGATCTGAATGCTGATCCCCTGTGTGAGAGAAAAGAATGGAATAAGCAGAACT
12001 GCCATGCTCAGAGAATCCTAGAGATACTGAAGATGTTCTTGGATAACACTAAATAGCAG
12061 CATTAGAAAAGTTAATGAGTGGTTTTCCAGAAGTGATGAAGTGTAGGTTCTGATGACTC
12121 ACATGATGGGGAGTCTGAATCAAATGCCAAAGTAGCTGATGTATTGGACGTTCTAAATGA
12181 GGTAGATGAATATTCTGGTTCTTCAGAGAAAATAGACTTACTGGCCAGTGATCCTCATGA

FIG. 10D

SUBSTITUTE SHEET (RULE 26)

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12241 GGCTTTAATATGTAAAAGTGAAAGAGTTCACTCCAAATCAGTAGAGAGTAATATTGAAGG
12301 CCAAATATTTGGGAAAACCTATCGGAAGAAGGCAAGCCTCCCCAACTTAAGCCATGTAAC
12361 TGAAAATCTAATTATAGGAGCATTGTACTGAGCCACAGATAATACAAGAGCGTCCCCT
12421 CACAAATAAATTAAAGCGTAAAAGGAGACCTACATCAGGCCTTCATCCTGAGGATTTTAT
12481 CAAGAAAAGCAGATTTGGCAGTTCAAAGACTCCTGAAATGATAAATCAGGGAACATAACCA
12541 AACGGAGCAGAATGGTCAAGTGATGAATATTACTAATAGTGGTCATGAGAATAAAACAAA
12601 AGGTGATTCTATTCAAGATGAGAAAAATCCTAACCCAATAGAATCACTCGAAAAAGAATC
12661 TGCTTTCAAACGAAAGCTGAACCTATAAGCAGCAGTATAAGCAATATGGAACCTCGAATT
12721 AAATATCCACAATTCAAAGCACCTAAAAAGAATAGGCTGAGGAGGAAGTCTTCTACCAG
12781 GCATATTCATGCGCTTGAACCTAGTAGTCAGTAGAAATCTAAGCCCACCTAATTGTACTGA
12841 ATTGCAAATTGATAGTTGTTCTAGCAGTGAAGAGATAAAGAAAAAAGTACAACCAAAAT
12901 GCCAGTCAGGCACAGCAGAAACCTACAACCTCATGGAAGGTAAAGAACCTGCAACTGGAGC
12961 CAAGAAGAGTAACAAGCCAAATGAACAGACAAGTAAAAGACATGACAGCGATACTTTCCC
13021 AGAGCTGAAGTTAACAAATGCACCTGGTCTCTTTACTAAGTGTTCAAATACCAGTGAACCT
13081 TAAAGAATTTGTCAATCCTAGCCTTCCAAGAGAAGAAAAAGAAGAGAAAACCTAGAAACAGT
13141 TAAAGTGTCTAATAATGCTGAAGACCCCAAAGATCTCATGTTAAGTGGAGAAAGGGTTTT
13201 GCAAACGAAAGATCTGTAGAGAGTAGCAGTATTTCAATTGGTACCTGGTACTGATTATGG
13261 CAATCAGGAAAGTATCTCGTTACTGGAAGTTAGCACTCTAGGGAAGGCAAAAACAGAACC
13321 AAATAAATGTGTGAGTCAGTGTGCAGCATTGTGAAAACCCCAAGGGACTAATTCATGGTTG
13381 TTCCAAAGATAATAGAAATGACACAGAAGGCTTTAAGTATCCATTGGGACATGAAGTTAA
13441 CCACAGTGGGAAACAAGCATAGAAATGGAAGAAAGTGAACCTTGATGCTCAGTATTTGCA
13501 GAATACATTCAAGGTTTTCAAAGCGCCAGTCATTTGCTCGTTTTCAAATCCAGGAAATGC
13561 AGAAGAGGAATGTGCAACATTCTCTGCCCCACTCTGGGTCTTAAAGAAAACAAAGTCCAAA
13621 AGTCATTTTTGAATGTGAACAAAAGGAAGAAAATCAAGGAAGAATGAGTCTAATATCAA
13681 GCCTGTACAGACAGTTAATATCACTGACAGGCTTTTCTGTGGTTGGTCAGAAAGATAAGCC
13741 AGTTGATAATGCCAAATGTAGTATCAAAGGAGGCTCTAGGTTTTGTCTATCATCTCAGTT
13801 CAGAGGCAACGAAACTGGACTCATTACTCCAAATAAACATGGACTTTTACAAAACCCATA
13861 TCGTATACCACCACTTTTTTCCCATCAAGTCATTTGTTAAACTAAATGTAAGAAAAATCT
13921 GCTAGAGGAAAACTTTGAGGAACATTCAATGTCACCTGAAAGAGAAATGGGAAATGAGAA
13981 CATTCCAAGTACAGTGAGCACAAATAGCCGTAATAACATTAGAGAAAATGTTTTTAAAGA
14041 AGCCAGCTCAAGCAATATTAATGAAGTAGGTTCCAGTACTAATGAAGTGGGCTCCAGTAT
14101 TAATGAAATAGGTTCCAGTGATGAAAAATTCAAGCAGAACTAGGTAGAAAACAGAGGGCC
14161 AAAATTGAATGCTATGCTTAGATTAGGGGTTTTGCAACCTGAGGTCTATAAACAAAGTCT
14221 TCCTGGAAGTAATTGTAAGCATCCTGAAATAAAAAAGCAAGAATATGAAGAAGTAGTTCA
14281 GACTGTTAATACAGATTTCTCTCCATATCTGATTTAGATAACTTAGAACAGCCTATGGG
14341 AAGTAGTCATGCATCTCAGGTTTGTCTGAGACACCTGATGACCTGTTAGATGATGGTGA
14401 AATAAAGGAAGATACTAGTTTTGCTGAAAATGACATTAAAGGAAAGTTCTGCTGTTTTTAG
14461 CAAAAGCGTCCAGAAAGGAGAGCTTAGCAGGAGTCTAGCCCTTTCACCCATACACATTT
14521 GGCTCAGGGTTACCGAAGAGGGGCCAAGAAATTAGAGTCTCAGAAGAGAACTTATCTAG
14581 TGAGGATGAAGAGCTTCCCTGCTTCCAACACTTGTTATTTGGTAAAGTAAACAAATATACC
14641 TTCTCAGTCTACTAGGCATAGCACCGTTGCTACCGAGTGTCTGTCTAAGAACACAGAGGA
14701 GAATTTATTATCATTGAAGAATAGCTTAAATGACTGCAGTAACCAGGTAATATTGGCAAA
14761 GGCATCTCAGGAACATCACCTTAGTGAGGAAACAAATGTTCTGCTAGCTTGTTCCTTC
14821 ACAGTGCAAGTGAATTGGAAGACTGACTGCAAAATACAAACACCCAGGATCCTTTCTTGAT
14881 TGGTTCTTCCAAACAAATGAGGCATCAGTCTGAAAGCCAGGGAGTTGGTCTGAGTGACAA
14941 GGAATTGGTTTCAGATGATGAAGAAAGAGGAACGGGCTTGAAGAAAATAATCAAGAAGA
15001 GCAAAGCATGGATTCAAACCTTAGGtattggaaccagggtttttgtgtttgccccagtcctat
15061 ttatagaagttagctaaatgtttatgcttttggggagcacattttacaaatttccaagta
15121 tagttaaaggaaactgcttcttaacttgaaacatgttccctcctaagggtgcttttcataga
15181 aaaaagtccctcacacagctaggacgtcatctttgactgaatgagctttaacatcctaata
15241 tactggtggacttacttctggtttcattttataaagcaaatccgggtgtcccaaagcaag

FIG. 10E

SUBSTITUTE SHEET (RULE 26)

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15301 gaatttaatcattttgtgtgacatgaaagtaaaccagtcctgccaatgagaagaaaaag
15361 acacagcaagttgcagcgtttatagtcctgcttttacatctgaacctctgttttgttatt
15421 taagGTGAAGCAGCATCTGGGTGTGAGAGTGAACAAGCGTCTCTGAAGACTGCTCAGGG
15481 CTATCCTCTCAGAGTGACATTTTAACCACTCaggtaaaaagcgtgtgtgtgtgcacat
15541 gcgtgtgtgtggtgtcctttgcattcagtagtatgtatccccacattcttaggtttgctga
15601 catcatctctttgaattaatggcacaattgtttgtggttcattgtcvvvvvvvvvvvn
15661 gngaattgtaatcctaataatttcnncnccnacttaaaagaataccactccaanggcacnca
15721 atacatcaatcaattgggaattgggattttccctcnctaacaatcantggaataatttca
15781 tggcattaattgcatgaatgtggttagattaaaagggtgttcattgctagaacttgtagttc
15841 catactaggtgatttcaattcctgtgctaaaattaatttgtatgatataatntcatttaa
15901 tggaaagcttctcaaagtatttcattttcttgggtaccatttatcgttttgaAGCAGAGG
15961 GATACCATGCAACATAACCTGATAAAGCTCCAGCAGGAAATGGCTGAAGTAGAAGCTGTG
16021 TTAGAACAGCATGGGAGCCAGCCTTCTAACAGCTACCCTTCCATCATAAGTGACTCTTCT
16081 GCCCTTGAGGACCTGCGAAATCCAGAACAAAGCACATCAGAAAAAGgtgtgtattgttgg
16141 ccaaacactgatatcttaagcaaaattcttctctccctttatctccttctgaagagta
16201 aggacctagctccaacattttatgatccttgctcagcacatgggtaattatggagccttg
16261 gttcttgtccctgctcacaactaatataaccagtcagagggacccaaggcagtcattcatg
16321 ttgtcatctgagataacctacaacaagtagatgctatggggagcccatggvvvvvvvvv
16381 vvccattgggtgctagcatctgtctgttgcattgcttgtgtttataaaattctgcctgata
16441 tacttgttaaaaaccaatttgtgtatcatagattgatgcttttgaaaaaatcagtatc
16501 taacctgaattatcactatcagaacaaagcagtaaagtagatttgttttctcattccatt
16561 taaagCAGTATTAACCTTACAGAAAAAGTAGTGAATACCCTATAAGCCAGAAATCCAGAAGG
16621 CCTTCTGCTGACAAGTTTGAGGTGTCTGCAGATAGTTCTACCAGTAAAAATAAAGAACC
16681 AGGAGTGGAAGGtaagaaacatcaatgtaaagatgctgtggtatctgacatctttattt
16741 atattgaactctgattgttaattttttaccatactttctccagttttttgcatacag
16801 gcatttatacacttttattgctctaggatacttcttttgtttaatcctatataggvvvvv
16861 vvvvvvvvgataagntcaagagatattttgataggtgatgcagtgatnaattgngaaaa
16921 tttntgctgcttcttaactctcccccggttcttcttctcctnccctccctccctnccct
16981 cccgctcctncccttcttcttccctccctccctcccttcttctcctnccctccctccct
17041 tctgtctacctttcttcttcttcttcttcttcttcttcttcttcttcttcttcttctt
17101 ctttcttcttcttcttcttcttcttcttcttcttcttcttcttcttcttcttcttctt
17161 agtcagtggtgctgatctcgnctcactgcaacctctgtctcccaggttcaagcaatttct
17221 ctgcctcagcctcccgagtagctgagattacaggcgccagccaccacaccagctactga
17281 cctgctttttvvvvvvvvvvvvaacagctgggagatatggtgcctcagaccaagcccat
17341 gttatatgtcaacctgacatattggcaggcaacatgaatccagacttctaggctgtcat
17401 gcgggctcttttttgcagtcatttctgatctctctgacatgagctgttctattatgct
17461 ttggctgcccaggaagtatgatttgcctttcacaattgggtggcgatggtttctccttc
17521 catttatctttctagGTCATCCCCCTCTAAATGCCCATCATTAGATGATAGGTGGTACAT
17581 GCACAGTTGCTCTGGGAGTCTTCAGAATAGAACTACCCATCTCAAGAGGAGCTCATTAA
17641 GGTGTGTGATGTGGAGGAGCAACAGCTGGAAGAGTCTGGGCCACACGATTGACGGAAC
17701 ATCTTACTTGCCAAGGCAAGATCTAGgtaaatatttcatctgctgtattggaacaaact
17761 ytgattttactctgaatcctacataaagatattctggttaaccaacttttagatgtacta
17821 gtctatcatggacacttttgttatacttaattaagccacttttagaaaaatagctcaagt
17881 gttaatcaagggtttacttgaaaattattgaaactgttaatccatctatattttaattaat
17941 ggtttaactaatgattttgaggatgwgaggctcktggtgtactctamatgtattatttca
18001 gggcaggcatagtggtcacgcctggttaatcccagtaaycmrgagcccgaggcaggtgga
18061 gccagctgaggtcaggagttcaagacctgtcttgccaacatggngnaaacctgtcttc
18121 ttcttaaaaaanacaaaaaaattaactgggtgtgcttaggtgnatgccccgnatccta
18181 gttnttcttgnnggttgaggaggagatcacnttggaccccgaggnggggtggggngg
18241 agcaggncaaaacacngaccagctgggggtggaagggaagccactcnaaaaannttnv
18301 vvvvvvvvvvtttttaggaaacaagctacttttgatttccaccaacacctgtattcat

FIG. 10F

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18361 gtaccattttttctcttaacctaactttattggtcttttttaattcttaacagagaccaga
18421 actttgttaattcaacattcatcggtgtgttaaattaaacttctccattctttcagAGGG
18481 AACCCCTTACCTGGAATCTGGAATCAGCCTCTTCTCTGATGACCCTGAATCTGATCCTTC
18541 TGAAGACAGAGCCCCAGAGTCAGCTCGTGTGGCAACATAACCATCTTCAACCTCTGCATT
18601 GAAAGTCCCCAATTGAAAGTTGCAGAATCTGCCAGAGTCCAGCTGCTGCTCATACTAC
18661 TGATACTGCTGGGTATAATGCAATGGAAGAAAGTGTGAGCAGGGAGAAGCCAGAATTGAC
18721 AGCTTCAACAGAAAGGGTCAACAAAAGAAATGTCCATGGTGGTGTCTGGCCTGACCCAGA
18781 AGAATTTgtgagtgtatccatattgtatctccctaataagacttaacaacattctgg
18841 aaagagttttatgttaggtattgtcaattaataacctagaggaagaaatctagaaaacaat
18901 cacagttctgtgtaatttaatttcgattactaatttctgaaaatttagaayvvvvvvvv
18961 vvvvnnccnnccccnaatctgaaatgggggtaaccccccccaaccganacntgggtng
19021 cntagagantttaatggcccnttctgaggnacanaagcttaagccagngacgtggancn
19081 atgngtgtttnttgtttggttacctccagcctgggtgacagagcaagactctgtctaaa
19141 aaaaaaaaaaaaaaaaaaatcgactttaaatagttccaggacacgtgtagaacgtgcaggat
19201 tgctacgtaggtaaacatatgccatggtgggataactagtattctgagctgtgtgctaga
19261 ggtaactcatgataatggaatatttgatttaatttcagATGCTCGTGTACAAGTTTGCCA
19321 GAAAACACCACATCACTTTAACTAATCTAATTACTGAAGAGACTACTCATGTTGTTATGA
19381 AAACAGgtataccaagaacctttacagaataaccttgcatctgctgcataaaaccacatga
19441 ggcgaggcacggtggcgcatgacctgtaatcgagcactttgggaggccgaggcgggcaga
19501 tcacgagattaggagatcgagaccatcctggccagcatggtgaaaccccgctctactan
19561 naaatggnaaaaattanctgggtgtggtcgctgcncctgtagtcacagctactcgtgagg
19621 ctgaggcaggagaatcactgaaccggggaaatggagggttcagtgcagagatcatnc
19681 ccctncattccagcctggcgacagagcaaggctccgtcncnnaaaaaataaaaaaacg
19741 tgaacaaataagaatatttgttgagcatagcatggatgtagtcttctaatagtcaatca
19801 attactttatgaaagacaaataatagttttgctgcttccctacctcctttgttttgggt
19861 taagatttgagtggtgggcccaggcacvvvvvvvvvvvgatctatagctagcctggcg
19921 tctagaagatgggtgttgagaagaggagtggaagatatttctctggtcttaacttca
19981 tatcagcctccccctagacttccaaatatccataacctgctggttataattagtgggtttt
20041 cagcctctgattctgtcaccagggttttagaatcataaatccagattgatcttgggagt
20101 gtanaaaactgaggctcttttagcttcttaggacagcacttctgattttgttttcaactt
20161 ctaactcctttgagtggttttcttctgagATGCTGAGTTTGTGTGTGAACGGACACTGA
20221 AATATTTTCTAGGAATTGCGGGAGGAAAATGGGTAGTTAGCTATTTCTgtaagtataata
20281 ctatttctccctcctccctttaaacctcagaattgcatttttacacctaacatttaac
20341 acctaaaggttttctgctgctgagctctgagttacaaaaggctctttaaattgtaatact
20401 aaactacttttatctttaatatcactttgttcaagataagctggtgatgctgggaaaatg
20461 ggtctcttttataactaataggacctaatctgctcctagcaatgttagcatatgagctag
20521 ggattttatataatagtcggcaggaaatccatgtgcacagncaaacttataatgtttaaat
20581 taaacatcaactctgtctccagaaggaaactgctgctacaagccttattaaagggtctg
20641 gcttttagagggaaggacctctcctctgtcattcttctctgtgctctttgtgaatcgctga
20701 cctctctatctccgtgaaaagagcagcttctctgctgtatgtaacctgtctttctatg
20761 atctctvvvvvvvvvvvnaaaaaacggggnngggantgggccttaaanccaaagggcna
20821 actccccaacctatnaaaaantgacnnggggattattaaaancggcgaggaaacatttcacn
20881 gccaactaatattgttaaattaaaaccaccacnctgcnccaaggagggaactgctgc
20941 tacaagccttattaaagggtgtggcttttagagggaaggacctctcctctgtcattcttc
21001 ctgtgctcttttgtgaatcgctgacctctctatgtccgtgaaaagagcagcttcttcgtc
21061 tgtatgtaacctgtcttttctatgatctcttagGGGTGACCCAGTCTATTAAGAAAGA
21121 AAAATGCTGAATGAGgtaagtacttgatgttataaactaaccagagatattcattcagtc
21181 atatagttaaaaatgtatttgccttccatcaatgcaccacttcttaacaatgcac
21241 aaattttccatgataatgaggatcatcaagaattatgcaggcctgcactgtggctcatac
21301 ctataatcccagcgctttgggaggctgaggcgcttggtatcvvvvvvvvvvvaattttt
21361 tgtatttttagtagagatgaggttcaccatgttggtctagatctggtgtcgaaacgtcctg

FIG. 10G

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21421 acctcaagtgatctgccagcctcagtcctcccaaagtgcaggattacaggggtgagccac
21481 tgcgcctggcctgaatgcctaaaatatgacgtgtctgctccacttccattgaaggaagct
21541 tctctttctcttatcctgatgggttggttttggtttctttcagCATGATTTTGAAGTCAG
21601 AGGAGATGTGGTCAATGGAAGAAACCACCAAGGTCCAAAGCGAGCAAGAGAATCCCAGGA
21661 CAGAAAGGtaaaagctccctccctcaagttgacaaaaatctcaccaccactctgtattc
21721 cactcccttttgagagatgggcccgttctattttgtaagacttattacatacatacacag
21781 tgctagatactttcacacaggttcttttttctactcttccatcccaaccacataaataagt
21841 attgtctctactttatgaatgataaaaactaagagatttagagaggctgtgtaatttgat
21901 tcccgctcgggttcagatcvvvvvvvvvvvttggcctgattggtgacaaaagtgaga
21961 tgctcagtcctgaatgacaaagaatgcctgtagagttgcaggtccaactacatatgcac
22021 ttcaagaagatcttctgaaatctagtagtgttctggacattggactgcttgtccctggga
22081 agtagcagcagaaatgatcggtggtgaacagaagaaaaagaaagctcttcccttttgaa
22141 agtctgtttttgaataaaagccaatattcttttataactagatttccctctctccatt
22201 cccctgtccctctctctctctctctctctccagATCTTCAGGGGGCTAGAAATCTGTTC
22261 TATGGGCCCTTCACCAACATGCCCACAGGtaagagcctgggagaaccccagagttccagc
22321 accagcctttgtcttacatagtgaggattataagcaaggtcccacgatgggggttccctc
22381 agattgctgaaatgttctagaggctattctatttctctaccactctccaaacaaaacagc
22441 acctaaatgttatcctatggcaaaaaaaactataccttgtcccccttctcaagagcatg
22501 aaggtggttaatagttaggattcagtatgttatgtgttcagatggcggtgagctgctgtt
22561 agtgccvvvvvvvvvvvtttgagagactatcaaacccttataccaagtggccttatgga
22621 gactgataaccagagttacatggcatatcagtggaattgacttaaaatccataccccta
22681 ctatttttaagaccattgtccttttgagagcagagagacagactctcccatgagaggctctg
22741 ctataagccttcatccggagagtgtagggtagaggcctgggttaagtatgcagattact
22801 gcagtgattttacatgtaaatgtccatttttagATCAACTGGAATGGATGGTACAGCTGTG
22861 TGGTGCTTCTGTGGTGAAGGAGCTTTCATCATTACCCTTGGCACAgtaagtattgggtg
22921 ccctgtcagtggtgggaggacacaatattctctcctgtgagcaagactggcacctgtcagt
22981 ccctatggatgccccctactgtagcctcagaagtcttctctgcccacatacctgtgccaaa
23041 agactccatvvvvvvvvvvvvggtggtacgtgtctgtagtccagctacttgggaggct
23101 gagatggaaggattgcttgagcccaggaggcagagggtggnanntacgctgagatcacac
23161 cactgcactccagcctgggtgacagagcaagaccctgtctcaaaaacaaacaaaaaaat
23221 gatgaagtgcaggttccagtagtccctactttgacactttgaatgctcttctctcctggg
23281 gatccagGGTGTCACCCAATTGTGGTTGTGCAGCCAGATGCCTGGACAGAGGACAATGG
23341 CTTCATGgtaaggtgcctcgcatgtacctgtgctattagtgggtccttgtgcatgggt
23401 ttggtttatcactcattacctggtgcttgagtagcacagttcttggcacatttttaaata
23461 tttgttgaatgaatggctaaaatgtctttttgatgtttttattgtttatttgttttatatt
23521 gtaaaagtaatacatgaactgtttccatggggtgggagtaagatatgaatgttcatcacv
23581 vvvvvvvvvvcagtaatcctnagaactcatacgaccgggccccctggagtcgntgntn
23641 gagcctagtccnggagaatgaattgacactaatctctgcttggttctctgtctccagCA
23701 ATTGGGCAGATGTGTGAGGCACCTGTGGTGACCCGAGAGTGGGTGTTGGACAGTGTAGCA
23761 CTCTACCAGTGCCAGGAGCTGGACACCTACCTGATACCCACAGATCCCCACAGCCACTAC
23821 TGA CTGCAGCCAGCCACAGGTACAGAGCCACAGGACCCCAAGAATGAGCTTACAAAGTGG
23881 CCTTTCAGGCCCTGGGAGCTCCTCTCACTCTTCAGTCCTTCTACTGTCTGGCTACTAA
23941 ATATTTTATGTACATCAGCCTGAAAAGGACTTCTGGCTATGCAAGGGTCCCTTAAAGATT
24001 TTCTGCTTGAAGTCTCCCTTGGAAAT

FIG. 10H